MOHAWK COLLEGE OF APPLIED ARTS AND TECHNOLOGY

COURSE OVERVIEW SURV EA141 / SURV CV104

1.0 ADMINISTRATION SECTION

1.1 **DEPARTMENT** - Building & Construction Sciences

FACULTY - Faculty of Engineering Technology

1.2 **COURSE NAME** - Surveying 1

1.3 **COURSE CODE** - SURV EA141 / SURV CV104

1.4 **DURATION** - **Total Hrs.:** 56

1.5 **PREREQUISITE COURSES** - none

1.6 **PRIOR LEARNING ASSESSMENT** - this course is eligible for PLA through challenge testing. Testing includes a written test and demonstration of use of equipment.

2.0 LEARNING REQUIREMENTS SECTION

2.1 **COURSE LEARNING OUTCOMES -**

To provide the student with an overview of the measurement, processing and analysis of spatial data relating to the natural and man made world. Various disciplines within the subject of Geomatics will be studied including surveying, GPS and GIS

Some generic skills will also be used in the course. Students will apply a wide variety of mathematical techniques with the degree of accuracy and precision required to solve surveying problems and make decisions. They will also interact with others in groups or teams in ways that contribute to effective working relationships and the achievement of goals.

2.2 COURSE CURRICULUM CONTENT

MODULE NUMBER	MAIN MODULES	TIME IN HOURS
1.	Surveying	1.0
2.	Elevation Measurement	20.0
3.	Distance Measurement	4.0
4.	The Direction of a Line	8.0
5.	Total Stations	8.0
6.	GPS	4.0
7.	GIS	2.0
8.	Tests & Reviews	9.0
		56.0

Topics may be added or deleted due to time constraints. Students will be informed of any changes.

2.3 REQUIRED AND OPTIONAL RESOURCES

REQUIRED TEXTBOOK(S)

SURVEYING, Course Notes for SURV CV104 / SURV EA141 / SURV10000 / SURV CN350, Mohawk College (2009)

ONLINE LEARNING SPACE

http://bb.mohawkcollege.ca

ADDITIONAL REFERENCES/BIBLIOGRAPHY

1. Surveying with Construction Applications, 7th Edition, Barry F. Kavanagh, Prentice-Hall (2010)
   Please Note: Students planning to carry on in Civil Technology or Civil Technician are advised to purchase this textbook.

SUPPLIES

- Calculator: The SHARP EL546W calculator is the only calculator permitted for writing tests. The instructors reserve the right to reset calculators prior to the commencement of tests.
- Survey Field Book
- Drafting Supplies as required

3.0 EVALUATION POLICIES AND PROCEDURES

3.1 EVALUATION INSTRUMENTS

Field Projects	- 20%
Mid-term Test	- 30%
Instrument Test	- 10%
Final Exam	- 40%
TOTAL	100%

3.2 GRADING AND CREDIT SYSTEM

(Refer to 7.0 Appendices and references in the Course Outline)

3.3 POLICIES AND PROCEDURES

It is the student's responsibility to familiarize him/herself with the College and Faculty of Engineering Technology policies regarding academics, testing, classroom conduct, and appeals.

The mid-term test will be conducted in the evening and each student must be able to produce a valid Student I.D. Card to write the test. If a student is unable to write a test for medical or other valid reasons, the instructor must be notified prior to the testing date and time. The student will be required to write the test through the Math Learning Center.

This surveying course has outdoor field sessions every week that are compulsory for students to take. Missing a field session without a valid medical note will result in receiving a zero for that week's work. Students may be required to do a pre-qualifying quiz prior to each lab to ensure they are prepared. Failure to complete a pre-qualifying quiz will result in a suspension of the student's mark for that lab, until the student meets the requirements set by his or her instructor.

4.0 REVISIONS/PROFESSOR

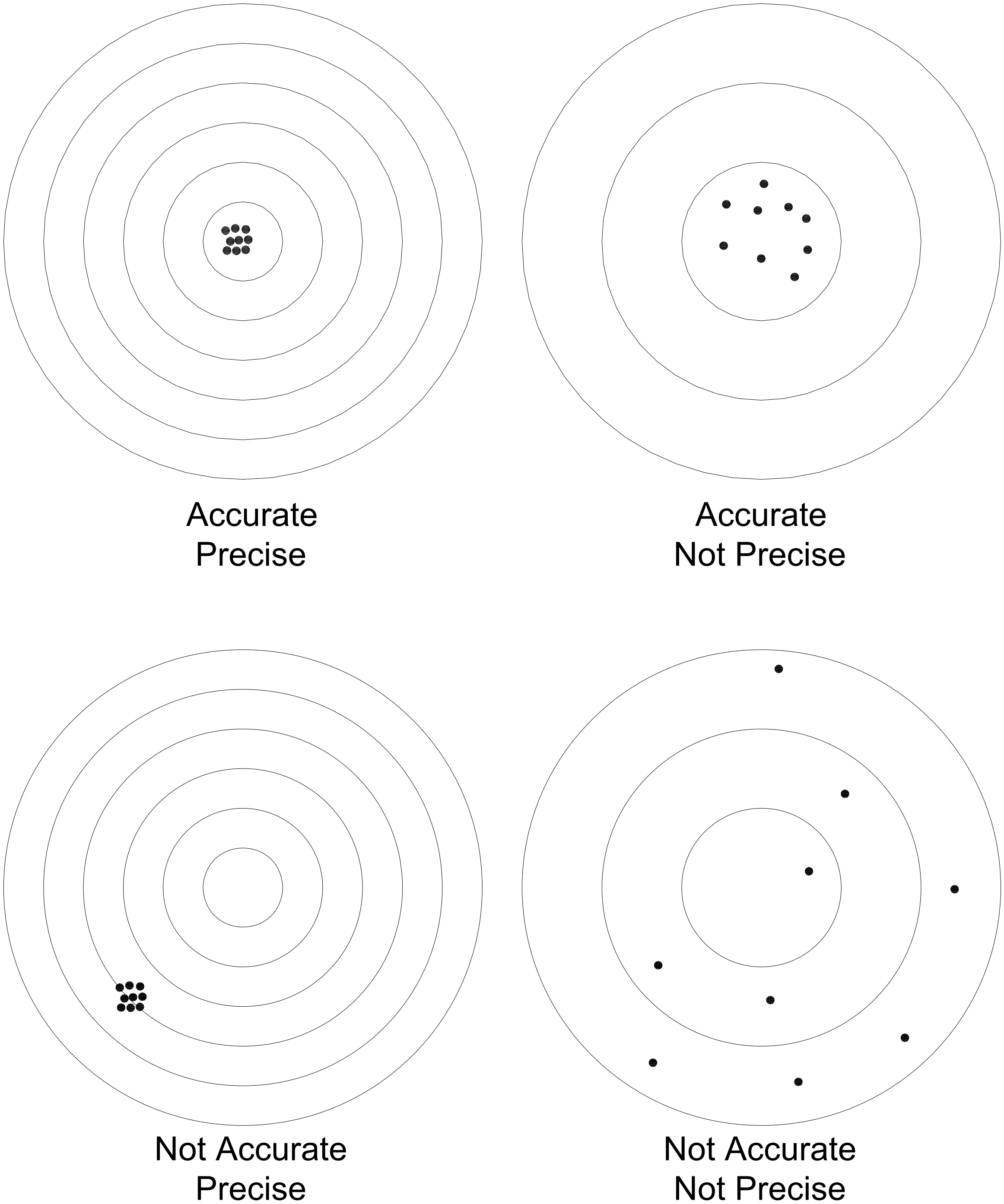
DATE	INSTRUCTOR(S)
2000	M. Keating
2007	D. Havercroft, J. Gibb, K. Smeaton, M. Keating, M. Shelley, P. Olynyk, S. Aird
2008	D. Havercroft, W. Houghton, K. Smeaton, M. Keating, M. Shelley, P. Olynyk, S. Aird
2009	D. Havercroft, W. Houghton, K. Smeaton, M. Shelley, P. Olynyk, S. Aird

SURVEYING SURV EA141 / CV104
MODULE 1: SURVEYING

Surveying and Geomatics are two terms which are used interchangeably by many. This module presents definitions for each and outlines the importance of surveying as well as presenting some basic definitions and introductory information.

Obj #	Learning Objective	Resources
1.1	Define the term “Geomatics”.	Lecture/bb.mohawkcollege.ca
1.2	What is “Surveying”? How does it differ from Geomatics?	Lecture/bb.mohawkcollege.ca Ref. Text 1
1.3	Why is surveying important?	Lecture/bb.mohawkcollege.ca Ref. Text 1
1.4	Name and describe the two types of surveys which exist.	Lecture/bb.mohawkcollege.ca Ref. Text 1
1.5	Name five classes of surveys and give an example of each.	Lecture/bb.mohawkcollege.ca Ref. Text 1
1.6	Define the terms “accuracy” and “precision”.	Lecture/bb.mohawkcollege.ca Ref. Text 1 Fig 1-A of class notes
1.7	Describe in general terms the type of errors inherent in surveying. How can they be avoided?	Lecture/bb.mohawkcollege.ca Ref. Text 1
1.8	Example questions and answers.	
1.9	Problems.	

Obj. 1.6



Shot Patterns of Four Marksman

Figure 1 - A

Example Questions & Answers

1. Not all students taking this course will end up being surveyors. Of what value is the course for those people?

   Everyone taking the course will be learning to think logically in order to complete the work and to present their findings in a professional manner. In addition they will be practising their math skills through the various calculations which are required. A knowledge of geomatics is useful for all branches of civil engineering, transportation engineering, architecture and municipal planning. Even if the an individual is not actively involved in surveying they are often exposed to site plans, etc. and must comprehend the relevance of the distance and elevation information shown there.

2. A true distance of 100.000 m is measured twice. The values obtained were 99.956 m and 99.976 m. Comment on the precision and accuracy of these values.

   These two values are precise. Let's look at the calculations to evaluate the level of precision.

$$\text{Precision} = \frac{\text{Maximum Discrepency}}{\text{Average Value of Measurements}}$$

$$\text{Precision} = \frac{99.976 - 99.956}{\left(\frac{99.976 + 99.956}{2}\right)} = \frac{0.020}{99.966} = \frac{1}{4998} \approx \frac{1}{5000}$$

   The average value 99.966 m is not so accurate. Let's look at the calculations to evaluate the level of accuracy.

$$\text{Accuracy} = \frac{\text{Amount of Error}}{\text{True Value}}$$

$$\text{Accuracy} = \frac{100 - 99.966}{100} = \frac{0.034}{100} = \frac{1}{2941} \approx \frac{1}{2900}$$

3. A building wall is known to be 47.923 m long. It is measured with a cloth tape several times with results equal to 46.75 m, 46.74 m and 46.76 m. Are these measurements precise? Are they accurate?

The cloth tape measures to 2 decimal places, with each measurement being within 2 centimetres of the others. This would demonstrate reasonable repeatability and they would be considered relatively precise. They are however inaccurate since they differ from the actual length by more than a metre in each case.

$$\text{Precision} = \frac{0.02}{46.75} = \frac{1}{2338} \approx \frac{1}{2300}$$

$$\text{Accuracy} = \frac{47.923\text{-}46.75}{47.923} = \frac{1.173}{47.923} \approx \frac{1}{41}$$

4. A horizontal distance is known to be 250.500 m long. It is re-measured and a result of 250.560 m is obtained. What is the accuracy ratio of this result?

If distance is known to be 250.500 m then measured distance is out by the difference between the two.

$$250.560 - 250.500 = 0.060 \text{ m}$$

This error is over a distance of 250.500 m

Therefore,

$$\text{Accuracy Ratio} = \frac{0.060}{250.500} = \frac{(0.060 \div 0.060)}{(250.500 \div 0.060)} = \frac{1}{4175} \approx \frac{1}{4200}$$

Problems

1. What is the difference between plane and geodetic surveying?

2. Why is it necessary for control surveys to be very accurate?

3. Why would a topographic survey typically be the first step in the development of a parcel of land?

4. The sides of a rectangular football field are known to be 329.268 m in total length. If the sides are measured with a cloth tape and a result of 330.012m is obtained, what is the accuracy ratio of this result?

5. The football field in question 4 is next measured with a steel tape and a result of 328.799 m is obtained. What is the accuracy ratio of this result?

6. Of the cloth and steel tape measurement results in questions 4 & 5, which is the most accurate?

7. The true distance of a line is 123.456 m. Two survey crews, crew A and crew B, determined the length of this line by taking the average of four measurements. Crew A measured 123.347, 123.265, 123.213, and 123.165 m. Crew B measured 123.651, 123.562, 123.523, and 123.512 m. Determine which crew was more accurate. Determine the precision of the crew's measurements.

8. Classify the following as either random or systematic errors;

   (i) A 30 m tape was broken and then repaired but is now only 29.980 metres long. It is used to measure a building.

   (ii) The reading on a tape is 27.650 but is recorded as 27.560.

   (iii) The dumpy level is not properly set up before using it.

SURVEYING SURV EA141 / CV104
MODULE 2: ELEVATION MEASUREMENT

Surveying is a three dimensional science as it measures and records spatial information from our three dimensional world. In surveying the measurement of elevation, distance and direction includes all that is required to record our world. This module concentrates on the measurement of elevations.

Obj #	Learning Objective	Resources
2.1	What is meant by "elevation"? Why is it important to measure such information?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.2	How is elevation measured? What information is required to start?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.3	What types of levels are used in surveying? How are they set up?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Ref. Figure 2-A to 2-E
2.4	How does one use a survey rod? How is it read?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.5	How does one establish the elevation of a point?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Ref. Figure 2-F to 2-H
2.6	How is elevation information recorded?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Ref. Figure 2-I to 2-V
2.7	What errors can occur in leveling? What checks are available to ensure the work is correct?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.8	How is profile leveling distinct from differential leveling?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.9	What revisions are made to the note taking procedure for profile leveling?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.10	What is a contour line? Of what use are contours?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.11	How are contour lines calculated? Of what use is leveling in the creation of contour lines?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.12	How can elevation information be set for construction purposes?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.13	What importance do volumes play in construction work? How is a volume calculated?	Lecture/bb.mohawkcollege.ca Ref. Text 1
2.14	Example Questions and Answers	
2.15	Problems	

Obj. 2.3

- Dumpy Level

- Tilting Levels

- Automatic Levels

- Digital Levels

Types of Leveling Instruments
Figure 2-A

Setting Up the Automatic Level

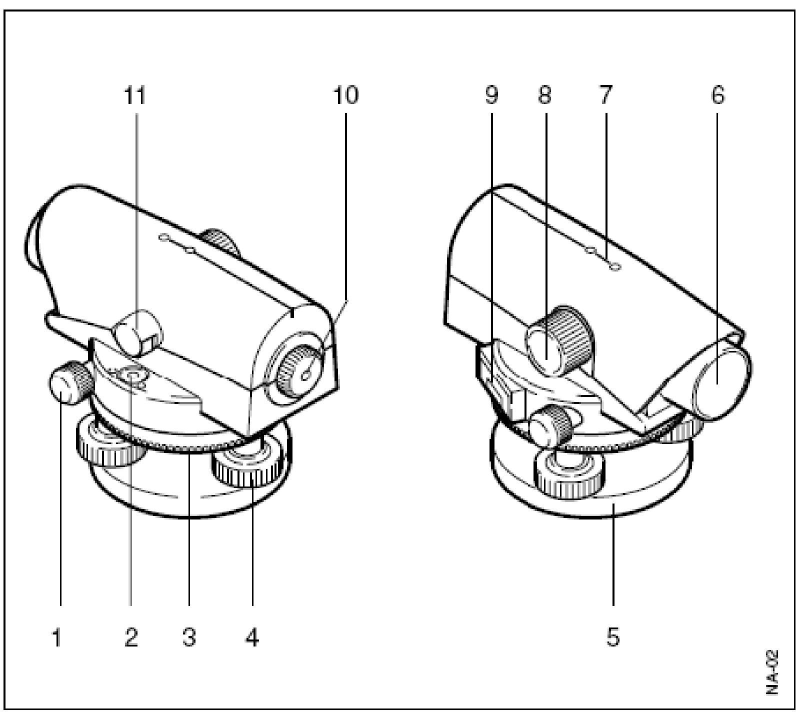
NOTE: See the "How to use an engineering level" video in the help topics section of the online learning space (bb.mohawkcollege.ca).

Leica NA720 Sokkia C330

The levels here at Mohawk College

Figure 2-B

Important parts



1 Endless drive (both sides)
2 Circular level
3 Knurled ring of adjustable horizontal circle
4 Footscrew
5 Base plate
6 Objective
7 Coarse aiming device (back/fore-sight for NA720/NA724; optical sight with point marking for NA728/NA730)
8 Focusing knob
9 Cover glass for angle reading (° or gon)
10 Eyepiece
11 Level mirror for NA720/NA724; Level prism for NA728/NA730

Parts of the Automatic Level

Figure 2-C

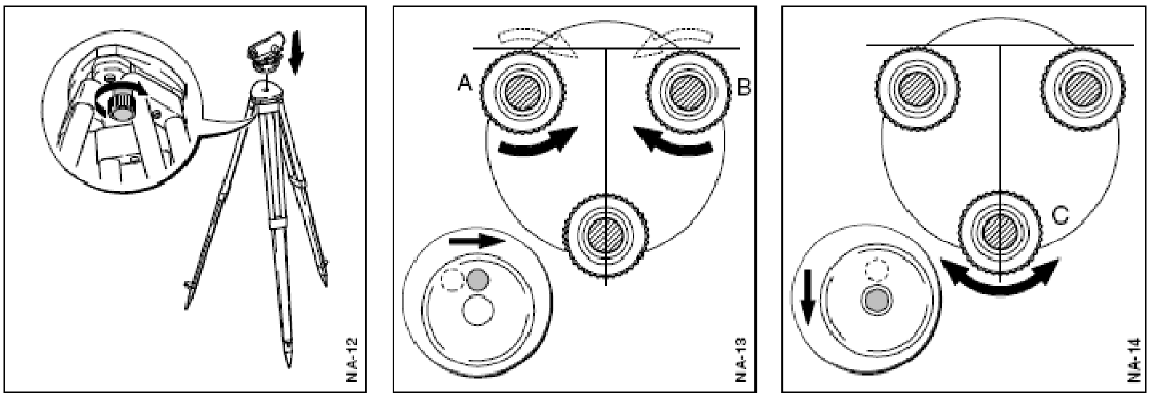
(Courtesy of Leica Geosystems User Manual for NA720, NA724, NA728, NA730, English Version 1.0)

1. Tripod legs should be adjusted to an appropriate height for the user. Securely mount the level to the tripod using the mounting bolt on the tripod.

2. Set the tripod on the ground so that the top of the tripod is approximately level (by eye). On a slope, 2 legs should be set extending down the hill and one leg set extending up the hill. Step on the foot pegs and press the legs firmly into the ground. Do not jar the instrument.

3. Centre the circular bubble by using the foot screws. See Figure 2-D for instructions on Centring the circular level. Once the circular level is centred, an automatic compensator inside the level precisely tunes the level for an accurate reading.

Levelling up



1. Place level onto tripod head. Tighten central fixing screw of tripod.
2. Turn footscrews of tribrach into its centre position.
3. Centre circular level by turning the foot screws.

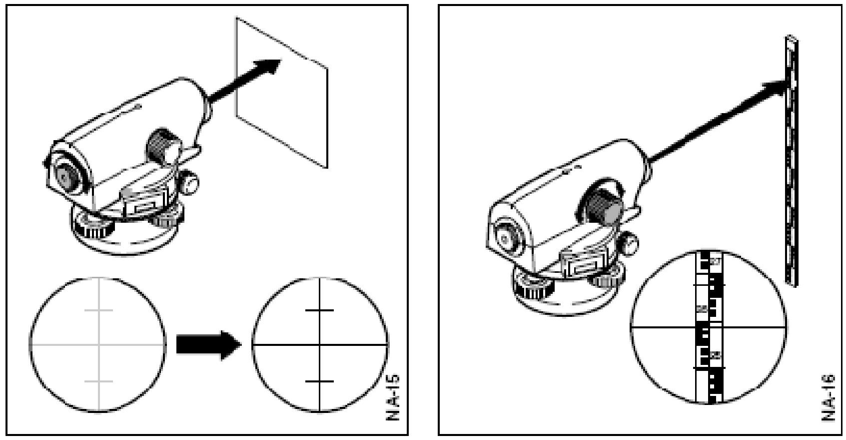
Centring the circular level

1. Turn foot screws A and B simultaneously in opposite directions until bubble is in the centre (on the imaginary "T").
2. Turn foot screw C until bubble is centred.

Centring the circular level
Figure 2-D
(Courtesy of Leica Geosystems User Manual for NA720, NA724, NA728, NA730, English Version 1.0)

4. Adjust the crosshairs for your eye and focus the telescope, See Figure 2-E.

Focusing telescope



1. Aim telescope against a bright background (e.g. white paper).
2. Turn eyepiece until reticule is sharp-focused and deep black. Now the eyepiece is adapted to your eye.
3. Aim telescope on staff using the coarse aiming device.
4. Turn focusing knob until image of staff is sharply focused. If the eye is moved up and down behind the eyepiece the image of the staff and the reticle may not be displaced against each other.

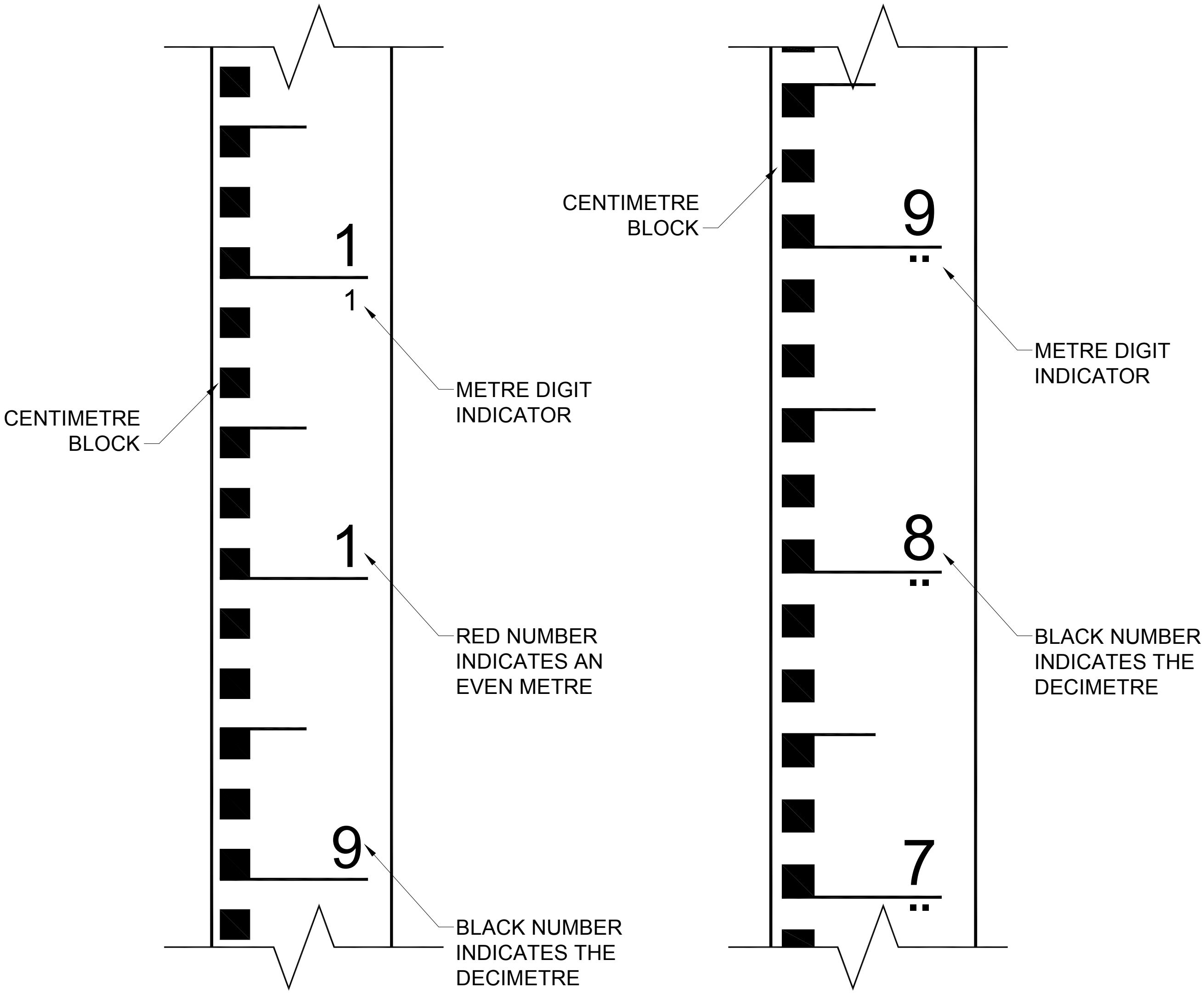
Adjusting the crosshairs and Focusing the telescope

Figure 2-E

(Courtesy of Leica Geosystems User Manual for NA720, NA724, NA728, NA730, English Version 1.0)

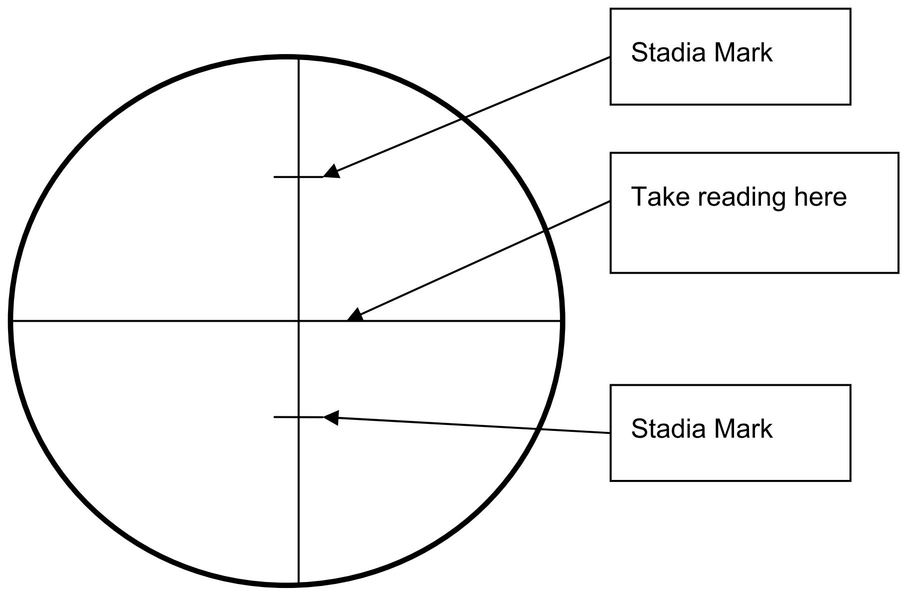
5. Now you are ready to start taking readings on the level rod.

Obj. 2.4



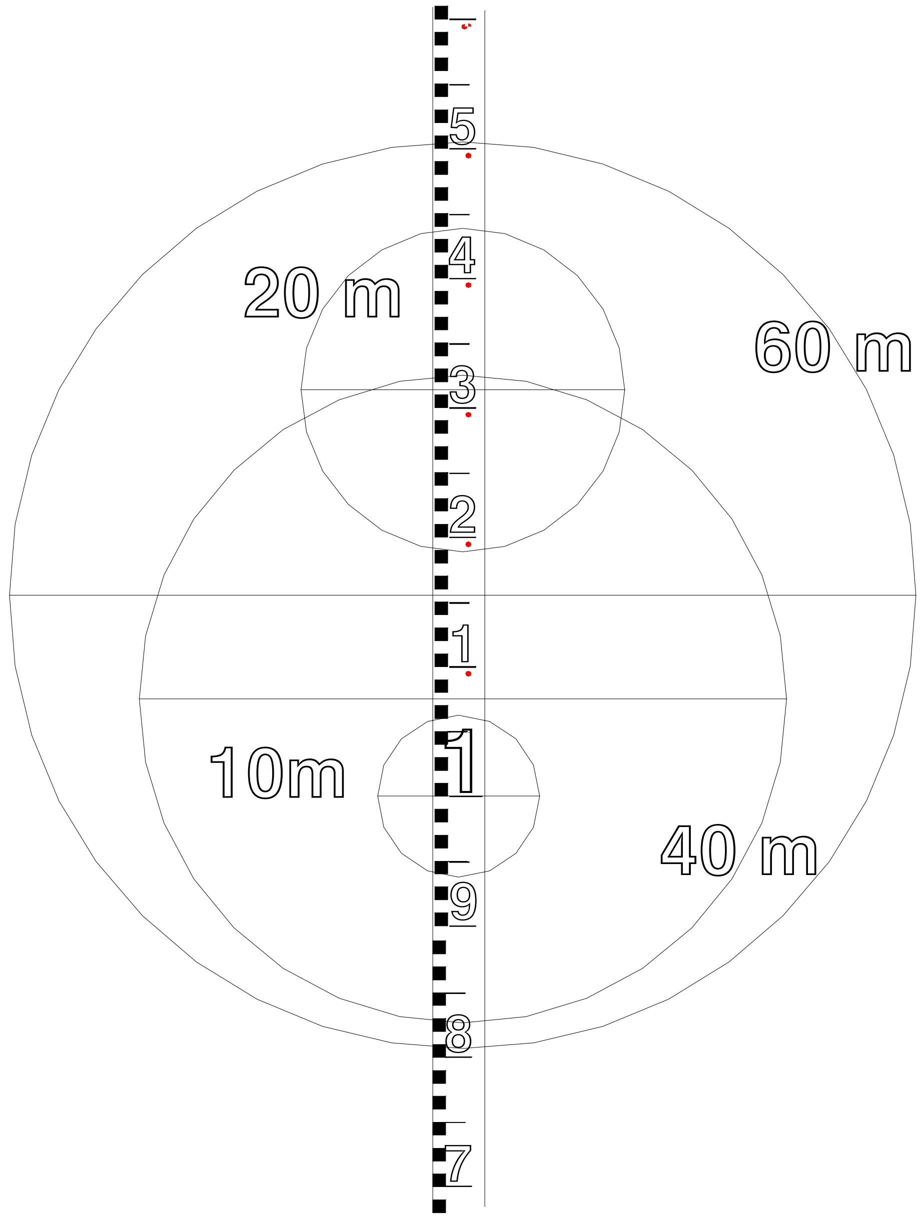
Types of Leveling Rods
Figure 2-F

Looking through the lens of a level, one must read the rod on the horizontal line that passes entirely through the field of vision. The other small marks above and below the horizontal line are the stadia marks used for calculation of distance only.



Looking through the lens of a Level
Figure 2-G

Examples of various rod readings are shown below. The amount of rod that would typically be visible from various distances is given along with the reading.



10 m – 1.001 20 m – 1.314 40 m – 1.076 60 m – 1.156

Rod Visibility and Readings for Various Distances
Figure 2-H

Obj. 2.5

Leveling Do's and Don'ts

1. Only set up the tripod on carpet or ground, never on tile, terrazzo, etc. Avoid setting up on asphalt or pavement as the potential of the instrument to fall or be kicked out of level is very high.

2. Never lean the instrument against a wall or lay on the ground.

3. Indoors: Walk with the instrument under your arm, telescope in front

   .

   Outdoors: Carry the instrument over your shoulder unless walking through trees, etc.

4. Hold the level by the telescope when fastening and unfastening the level onto the base plate.

5. Never force or over-tighten the screws (made of brass).

6. **SAFETY VEST MUST BE WORN FOR ALL FIELD WORK!!!**

7. Do not swing rods around inadvertently (be careful).

8. If the level is set up on wood, concrete, or asphalt, set the legs far enough apart so that the instrument will not be blown over

Leveling Procedure (Refer to question 1 in "Example Questions and Answers")

Step 1: Set up the level in a location where the rod will be visible at BM #1 and at turning point #1 (TP #1). Try to set up half way between the two points. Level the instrument and check the focus (cross-hairs).

Step 2: Take a backsight (BS) on BM #1, record the reading in the field book under the BS column, and then confirm the reading logged by re-reading the BS. The backsight on BM #1 was found to be 2.817.

Step 3: Calculate and record the height of instrument (HI):

$$\begin{aligned} HI &= \text{elev. of BM \#1} + \text{BS on BM \#1} \\ &= 195.582 + 2.817 \\ &= 198.399 \end{aligned}$$

Step 4: Move the rod to TP #1 and take a foresight (FS) on TP #1, record the reading in the field book under the FS column and then confirm the reading logged by re-reading the FS. The foresight on TP #1 was found to be 1.479.

Step 5: Calculate and record the elevation of TP #1:

elev	=	HI at the first setup - FS on TP #1
	=	198.399 - 1.479
	=	196.920

Steps 6-15: The level is then moved to the second setup, the process is repeated and finally repeated again with a third setup until the elevation of BM #2 is found.

Step 16: The calculations are then checked by a different crew member. This is done by adding all the BS readings together and subtracting from this sum the sum of all the FS readings. If the calculations (reductions) are correct, this should equal the change in elevation in going from BM #1 to BM #2. If there is a discrepancy, the error(s) must be found and corrected before advancing.

NOTE: Good communication is essential. The following signals are given by the instrument operator (instrument person) to the person holding the rod (rod person):

require a TP: hand above head, moving in a circular motion

reading complete: both arms extended sideways, wave up and down

raise the rod: point and move hand upward

rod not vertical: praying hands over head, lean in direction rod should be moved

wave the rod: turn sideways, push hands back and forth

Two way radios or similar devices can be used to improve the communication barrier when crew members get further away.

Obj. 2.6

Field Notes

Importance of Good Note Keeping

1. A survey or portion thereof is rendered useless if the notes are carelessly recorded and documented, falsified, lost or made grossly incorrect in any way. Defective notes result in a waste of time and money.

2. Other people will have to read, understand, and use your notes.

3. Field books may be entered as evidence in court.

General Points on Note Keeping

4. All notes should be done in pencil with a 2H-4H lead.

5. Print all notes using a neat style of free-hand lettering.

6. Straight edges and circle templates should be used for all sketches. All plan view sketches should have a north arrow. The text must be oriented so that it can be read looking towards the top of the page or by looking to the left of the page.

7. All pages should be numbered. The index at front of the book should give project descriptions, page numbers, and the date.

8. The cover of the field book should show the student name, class and course code at the top, printed neatly using a permanent marker:

Example:	Name:	Bob Plumb
	Class:	1DT61
	Course:	EA141

9. Do not erase numerical entries in a field book except when necessary to alter a sketch or identifier or otherwise clarify the notes. If a mistake is made in entering a value, draw a line through the entire number (all the digits) and enter the correct value beside or above the incorrect value. Because field books may be submitted as evidence in litigation proceedings, any erasure will cast doubt on its value as evidence.

10. Reduce the notes (calculate and record the elevations and the height of instrument) as the readings are being taken.

11. The precision of measurements should be reflected by the number of digits

recorded in the field book. For example, if a distance is measured to the nearest mm, then a result of 270.120 m should be shown as such and not as 270.12 m.

12. The note-keeper should ensure that all the necessary information is recorded immediately. Nothing should be trusted to memory to be recorded later. As a check, the note-keeper should repeat to the observer all the measurements.

13. Print the word "COPY" at the top of the page of copied notes.

14. Show "VOID" on notes that should not be used.

15. Never remove pages from a field book.

16. The first time a benchmark is referenced in a field book, a full description must be given. Every subsequent reference to that benchmark requires at least an abbreviated description that references the page in the field book where the full description appears.

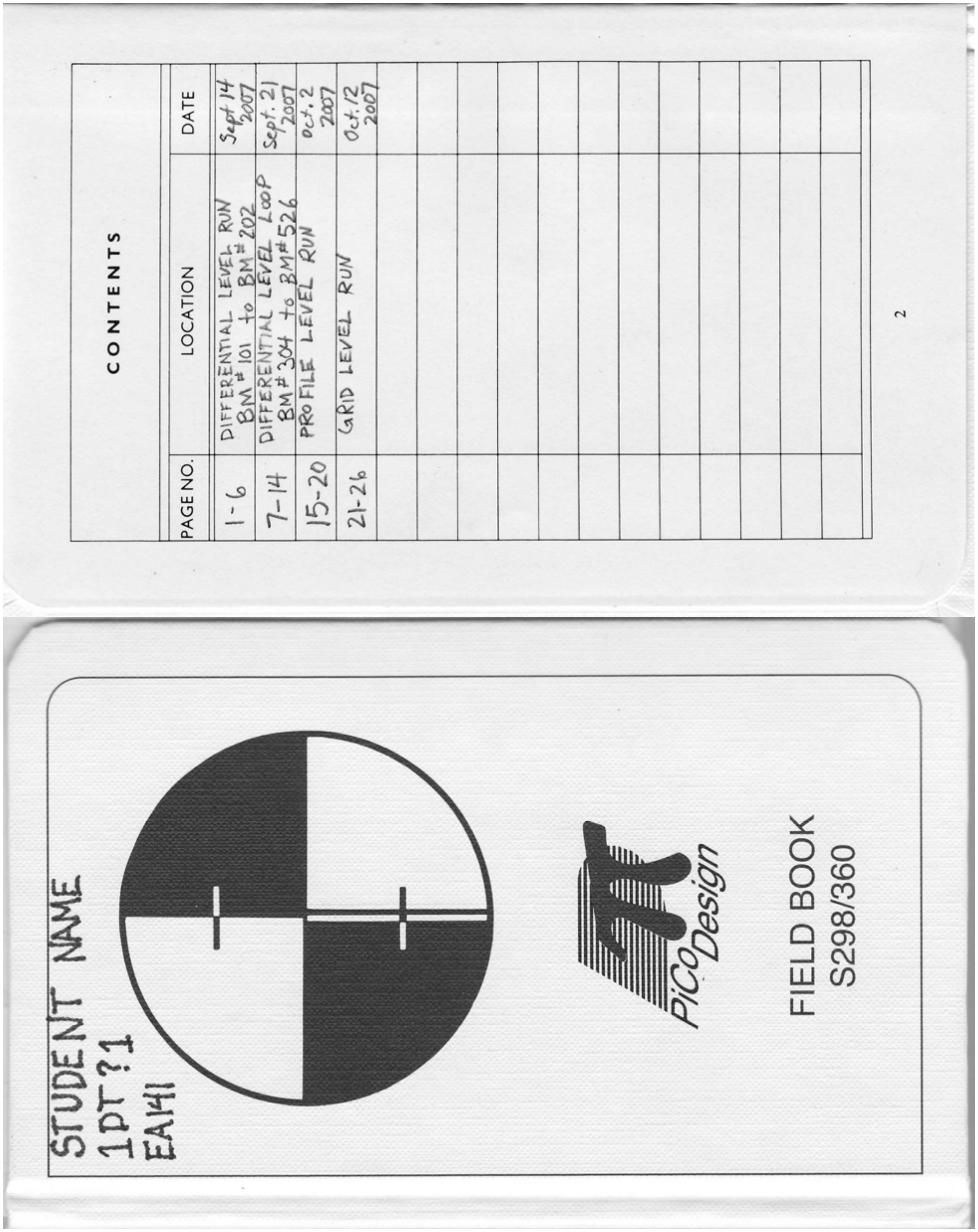
You are expected to take your turn in recording the notes in the field using your book. Each crew member is expected to keep their notes up to date. At the end of each field session, the note-keeper's book is to be submitted for evaluation. The book will be returned in time for the other crew members to copy the notes before the next field session. Each crew member must bring their up-to-date field book to each class. Other field books, in addition to the note-keeper's, may be called in for checking at the end of any class.

Title Page

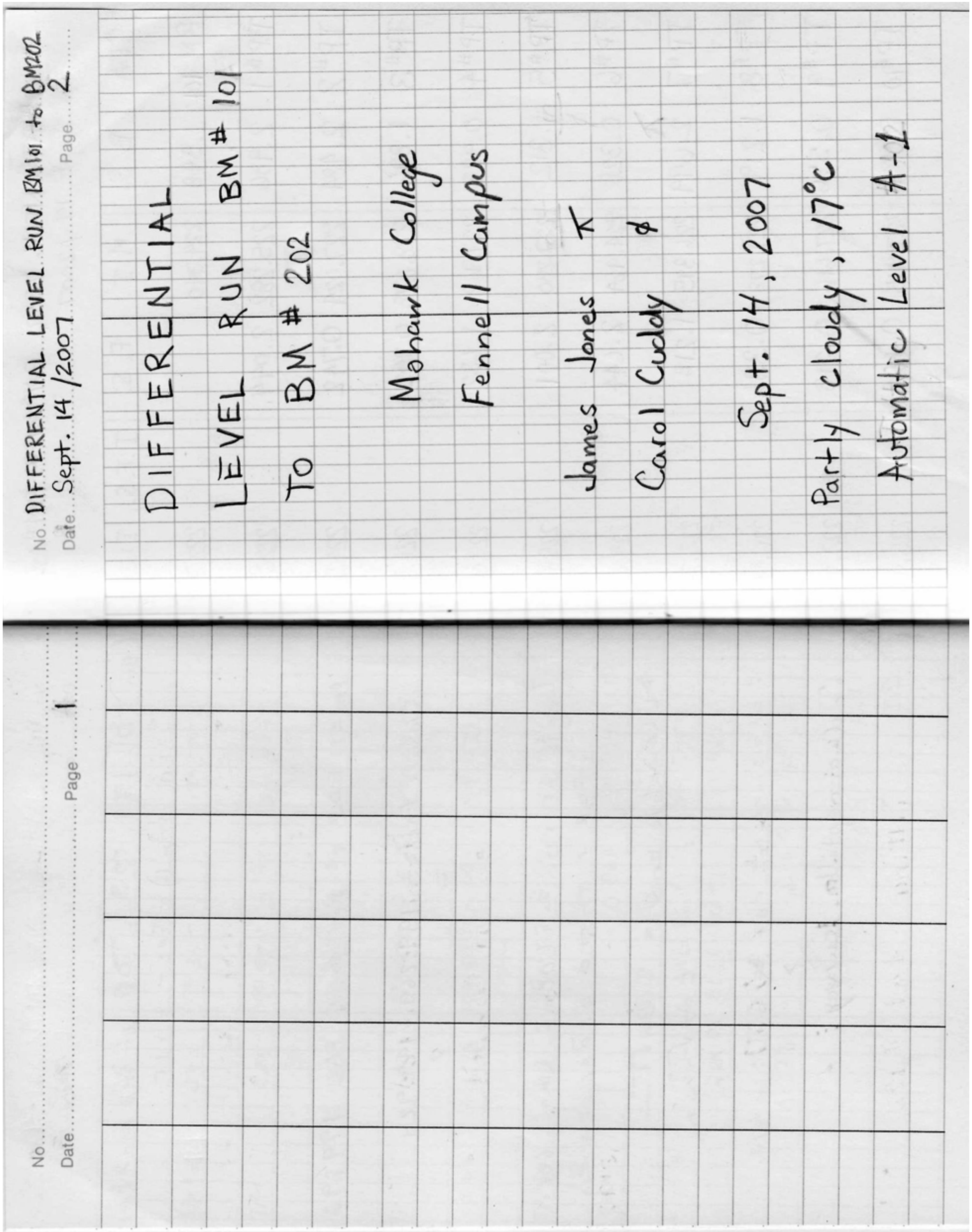
The title (right-hand) page should have the following information:

- *project description and location*
- *survey crew member names and duties:*
  Jim Smith instrument
  Alice Jones note-keeper
  Jason Wong rod
- *date*
- *weather:*
    temperature
    overcast, sunny, precipitation (if any), etc.
    windy, calm, etc.
- *type and number of the instrument used.*

Sample field notes are shown in Figures 2-I to 2-X. (next page)



Typical Front Cover and Table of Contents
Figure 2-I



No. DIFFERENTIAL LEVEL RUN BM101 to BM202
Date Sept. 14 /2007 Page 2

DIFFERENTIAL
LEVEL RUN BM # 101
TO BM # 202

Mohawk College
Fennell Campus

James Jones
Carol Cuddy

Sept. 14, 2007
Partly cloudy, 17°C
Automatic Level A-1

No.
Date Page 1

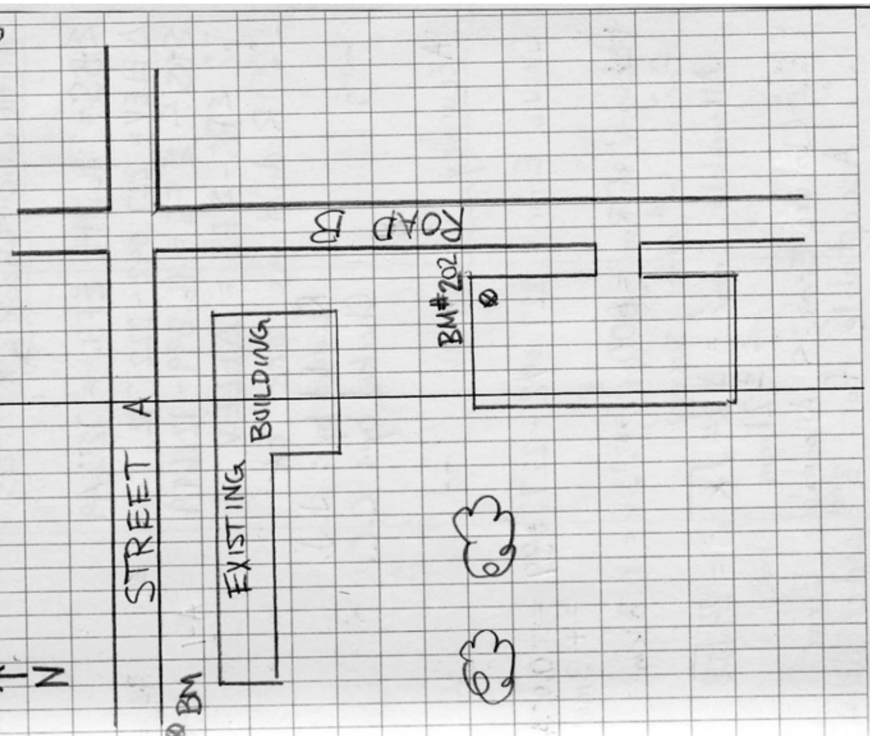
Typical Differential Leveling Run Notes
Figure 2-J

No. DIFFERENTIAL LEVEL BM#101 to BM#202
Date Sept 14 / 2007 Page 3

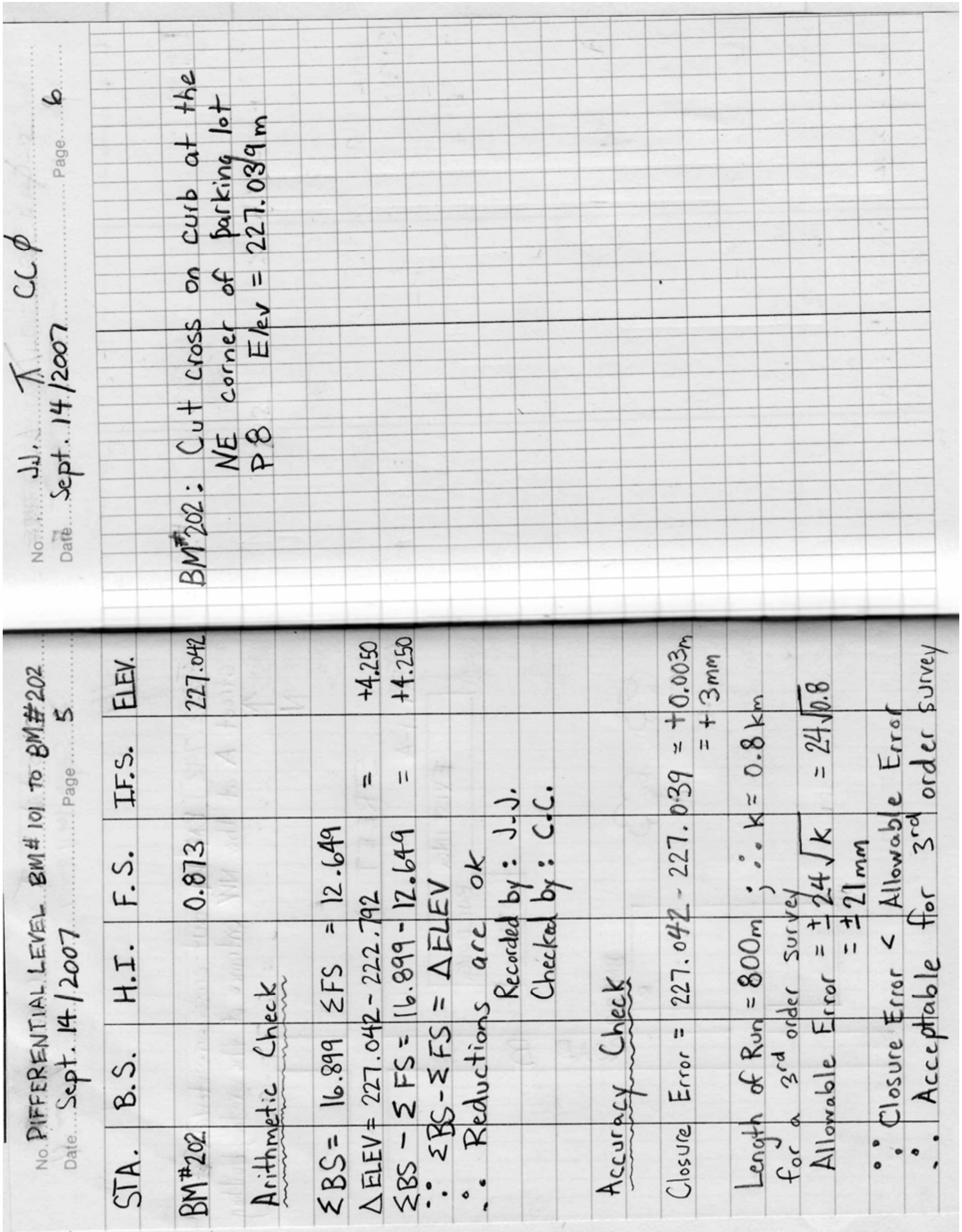
STA.	B.S.	H.I.	F.S.	I.F.S.	ELEV.
BM#101	1.548	224.340			222.792
TP#1	2.986	225.282	2.044		222.296
TP#2	2.484	227.024	0.742		224.540
TP#3	1.896	228.678	0.242		226.782
TP#4	0.923	227.969	1.632		227.046
TP#5	1.312	227.280	2.001		225.968
TP#6	0.328	224.964	2.644		224.636
TP#7	2.649	226.395	1.218		223.746
TP#8	1.219	227.278	0.336		226.059
TP#9	0.556	227.616	0.218		227.060
TP#10	0.998	227.915	0.699		226.917

No. J J T C C
Date Sept 14 / 2007 Page 4

[222.792] BM#101 - cut cross on sidewalk of Street A at the NW entrance of the existing building



Typical Differential Leveling Run Notes (continued)
Figure 2-K



No. DIFFERENTIAL LEVEL BM# 101 TO BM# 202
Date Sept. 14/2007 Page 5

STA.	B.S.	H.I.	F.S.	I.F.S.	ELEV.
BM#202			0.873		227.042

Arithmetic Check

$\Sigma BS = 16.899$ $\Sigma FS = 12.649$

$\Delta ELEV = 227.042 - 222.792 = +4.250$

$\Sigma BS - \Sigma FS = 16.899 - 12.649 = +4.250$

$\therefore \Sigma BS - \Sigma FS = \Delta ELEV$

$\therefore$ Reductions are ok

Recorded by: J.J.
Checked by: C.C.

Accuracy Check

Closure Error = $227.042 - 227.039 = +0.003m = +3mm$

Length of Run = 800m ; $\therefore$ k = 0.8 km

for a 3rd order survey

Allowable Error = $\pm 24\sqrt{k} = 24\sqrt{0.8} = \pm 21mm$

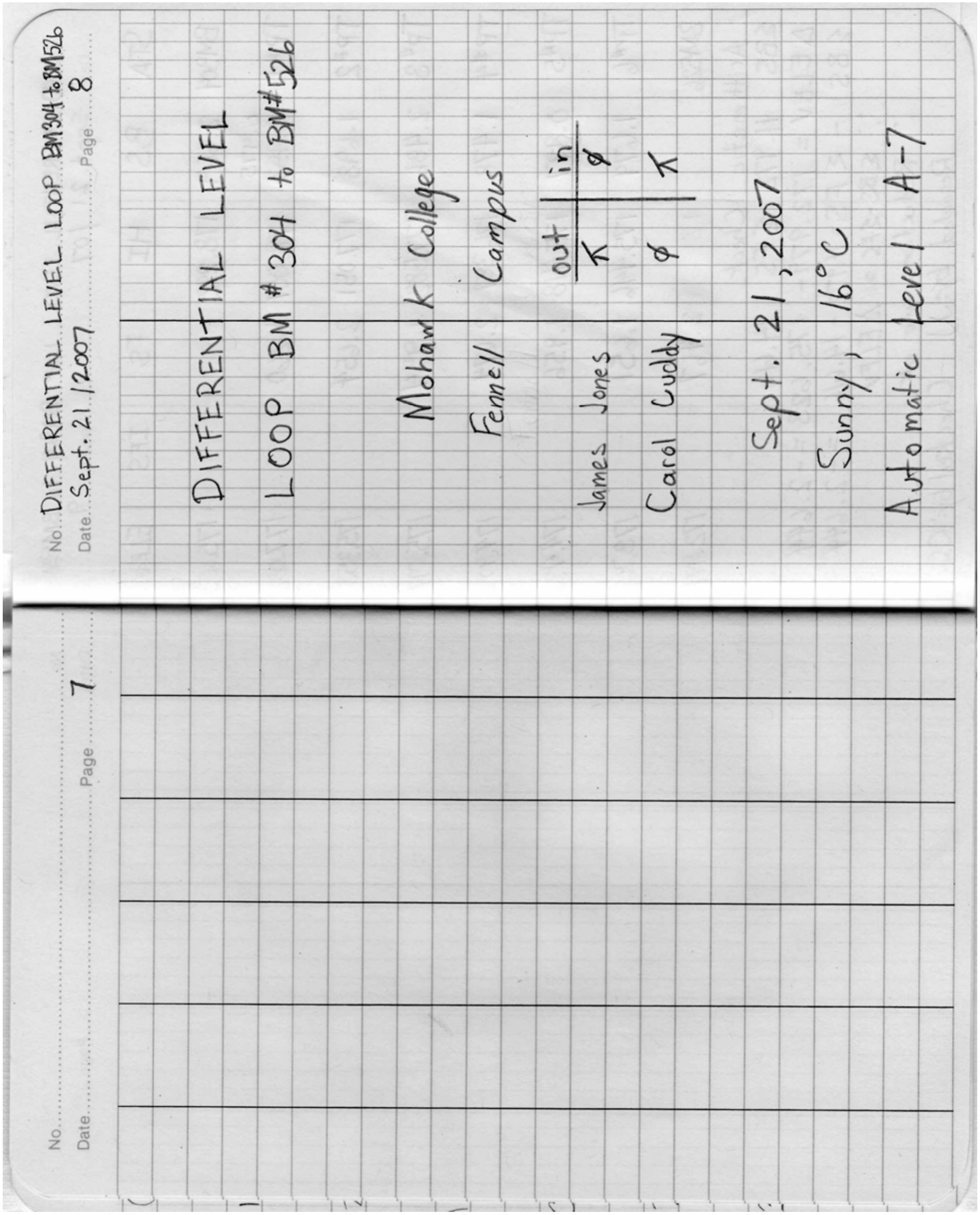
$\therefore$ Closure Error < Allowable Error

$\therefore$ Acceptable for 3rd order survey

No. J.J. ⊼ CC Ø
Date Sept. 14/2007 Page 6

BM#202: Cut cross on curb at the NE corner of parking lot P8 Elev = 227.039 m

Typical Differential Leveling Run Notes (continued)
Figure 2-L



Typical Differential Leveling Loop Notes
Figure 2-M

No. DIFFERENTIAL LEVEL LOOP BM304 to BM526
Date Sept. 21 /07 Page 9

STA.	BS	HI	FS	IFS	ELEV
BM304	2.669	178.292			175.623
TP#1	0.975 ~~0.957~~	178.007	1.260		177.032
TP#2	1.698	177.051	2.654		175.353
TP#3	2.486	177.583	1.954		175.097
TP#4	1.478	176.387	2.674		174.909
TP#5	0.987	175.418	1.956		174.431
TP#6	1.679	175.446	1.651		173.767
BM526			2.467		172.979

Arithmetic Check
ΣBS 11.972 ΣFS 14.616
$\Delta ELEV$ = 172.979 − 175.623 = −2.644
$\Sigma BS - \Sigma FS$ = 11.972 − 14.616 = −2.644
$\therefore \Sigma BS - \Sigma FS = \Delta ELEV$
$\therefore$ Reductions are ok

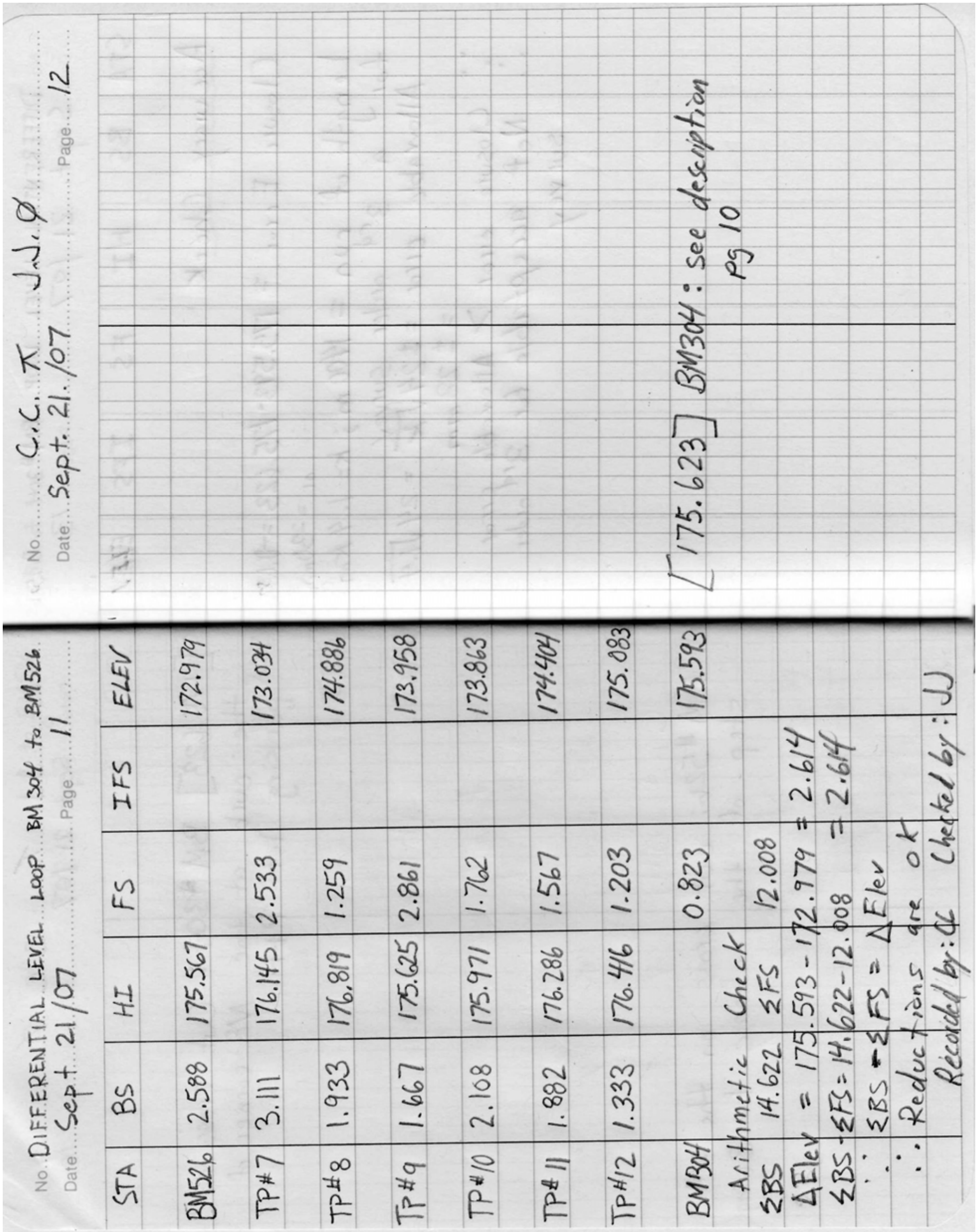
Recorded by: JJ Checked by: C.C.

No. J.J. ⊼ C.C. Ø
Date Sept. 21 /07 Page 10

[175.623] BM #304: Cut cross on the curb at the NE corner of parking lot P14

BM #526: cut cross on the 3rd step of the entrance to B wing

Typical Differential Leveling Loop Notes (continued)
Figure 2-N



No. DIFFERENTIAL LEVEL LOOP BM 304 to BM526
Date Sept 21/07 Page 11

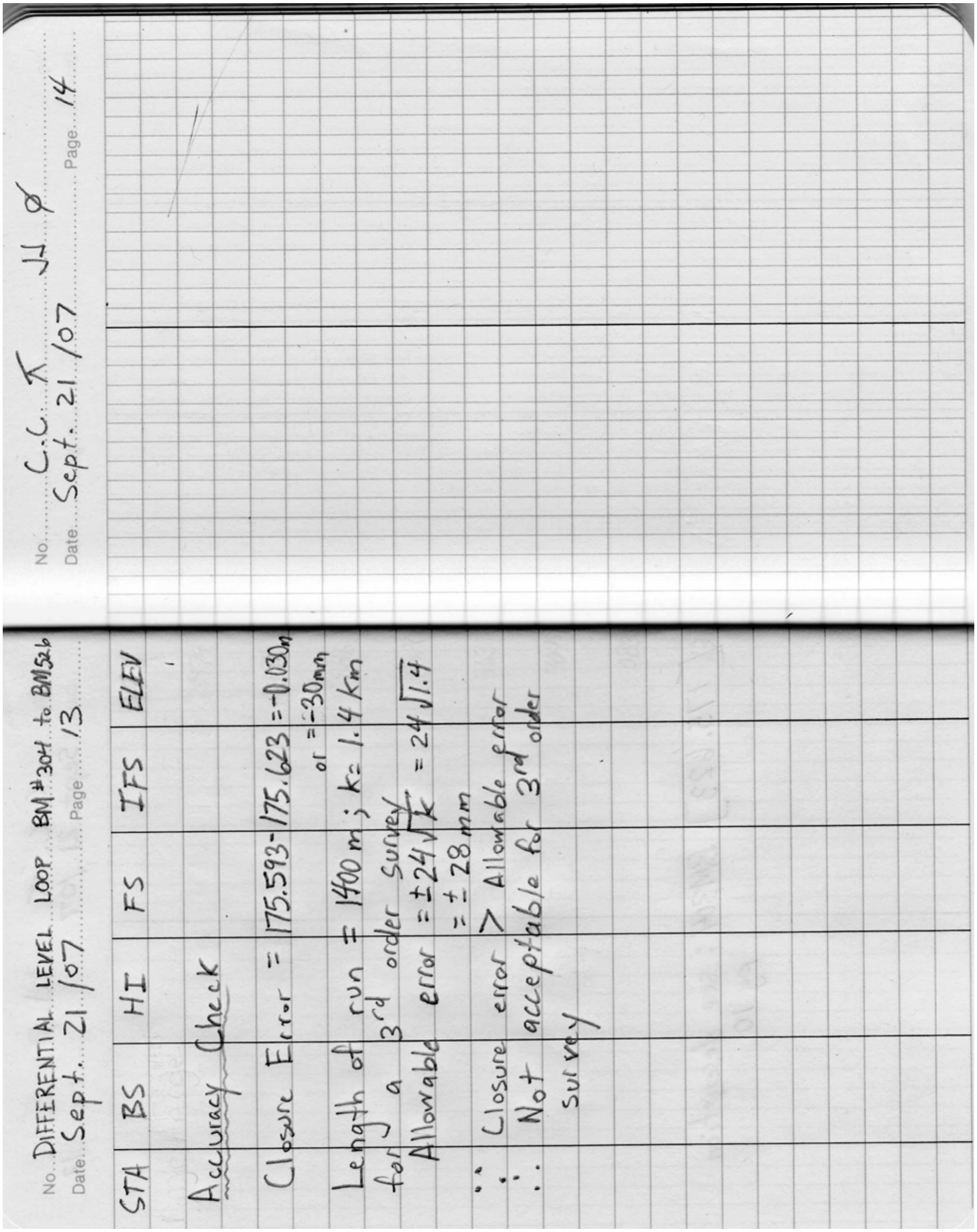
STA	BS	HI	FS	IFS	ELEV
BM526	2.588	175.567			172.979
TP#7	3.111	176.145	2.533		173.034
TP#8	1.933	176.819	1.259		174.886
TP#9	1.667	175.625	2.861		173.958
TP#10	2.108	175.971	1.762		173.863
TP#11	1.882	176.286	1.567		174.404
TP#12	1.333	176.416	1.203		175.083
BM304			0.823		175.593

Arithmetic Check
ΣBS 14.622 ΣFS 12.008
ΔElev = 175.593 - 172.979 = 2.614
ΣBS - ΣFS = 14.622 - 12.008 = 2.614
∴ ΣBS - ΣFS = ΔElev
∴ Reductions are ok
Recorded by: CC Checked by: JJ

No. C.C. T. J.J.Ø
Date Sept. 21/07 Page 12

[175.623] BM304 : see description pg 10

Typical Differential Leveling Loop Notes (continued)
Figure 2-O



No. DIFFERENTIAL LEVEL LOOP BM #304 to BM526
Date Sept. 21/07 Page 13

STA	BS	HI	FS	IFS	ELEV

Accuracy Check

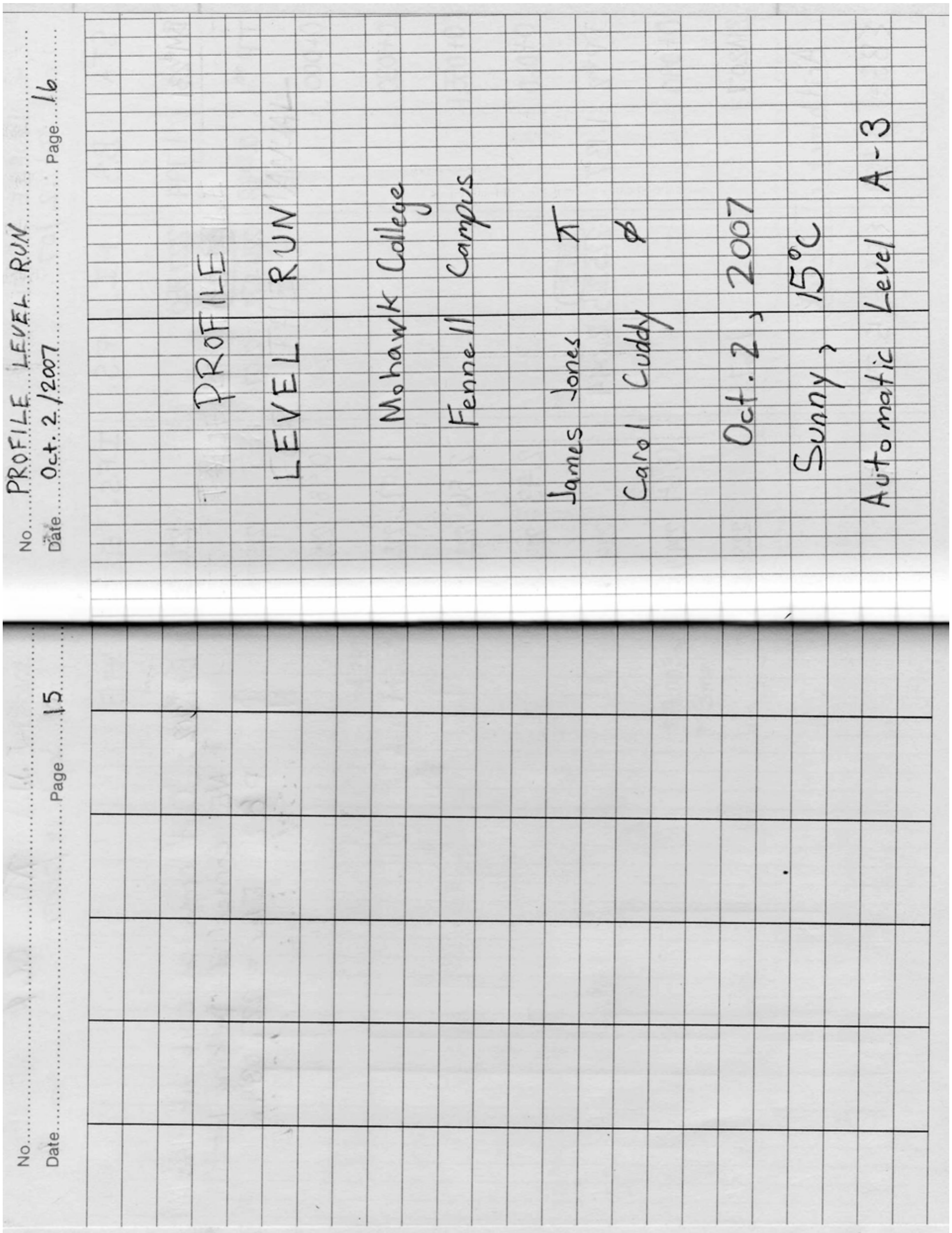
Closure Error = 175.593 - 175.623 = -0.030 m
or = -30 mm

Length of run = 1400 m ; k = 1.4 km
for a 3rd order survey
Allowable error = ± $24\sqrt{k}$ = $24\sqrt{1.4}$
= ± 28 mm

∴ Closure error > Allowable error
∴ Not acceptable for 3rd order survey

No. C.C. ⊼ JJ ⌀
Date Sept. 21/07 Page 14

Typical Differential Leveling Loop Notes (continued)
Figure 2-P



Typical Profile Leveling Notes
Figure 2-Q

PROFILE LEVEL RUN
Date Oct. 2 /07 Page 17

STA.	B.S.	H.I.	F.S.	I.F.S.	ELEV.
BM#231	1.794	227.850			226.056
TP#1	0.498	226.27 226.272	2.076		225.774
0+000				0.98	225.29
0+030				1.07	225.20
0+055.1				2.56	223.71
0+060				2.43	223.84
TP#2	1.137	225.37 225.365	2.044		224.228
0+090				0.64	224.73
BM207			1.676		223.689
Arithmetic Check					
ΣBS =	3.429	ΣFS =	5.796		

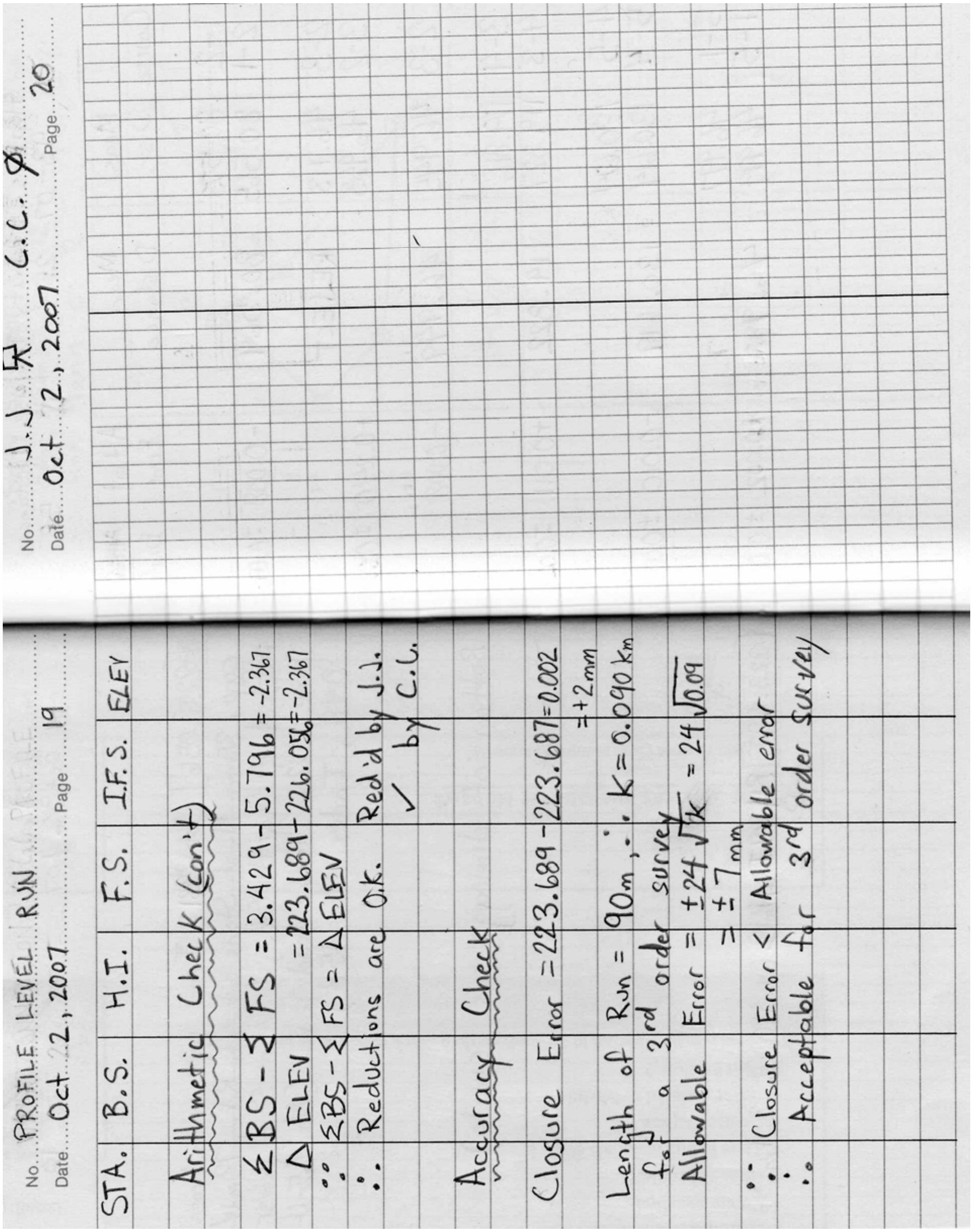
No. J.J. C.C. Ø
Date Oct. 2 /07 Page 18

[226.056] BM#231: Iron pipe with brass cap, 35m N of Stone Church Rd., 73m W of ℄ Garth St., 0.6 m S of power pole, 1.2m above road level (No. 65-U-048, Index No. 153)

Bottom of drainage run (swale)

[223.687] BM207 Iron Pin @ 0+110 @ 13.1m Rt ℄

Typical Profile Leveling Notes (continued)
Figure 2-R



No. PROFILE LEVEL RUN
Date Oct 2, 2007 Page 19

STA.	B.S.	H.I.	F.S.	I.F.S.	ELEV

Arithmetic Check (con't)

$\Sigma BS - \Sigma FS = 3.429 - 5.796 = -2.367$

$\Delta ELEV = 223.689 - 226.056 = -2.367$

$\therefore \Sigma BS - \Sigma FS = \Delta ELEV$

$\therefore$ Reductions are O.K. Red'd by J.J.

✓ by C.C.

Accuracy Check

Closure Error $= 223.689 - 223.687 = 0.002$
$= +2mm$

Length of Run $= 90m$, $\therefore K = 0.090$ km

for a 3rd order survey

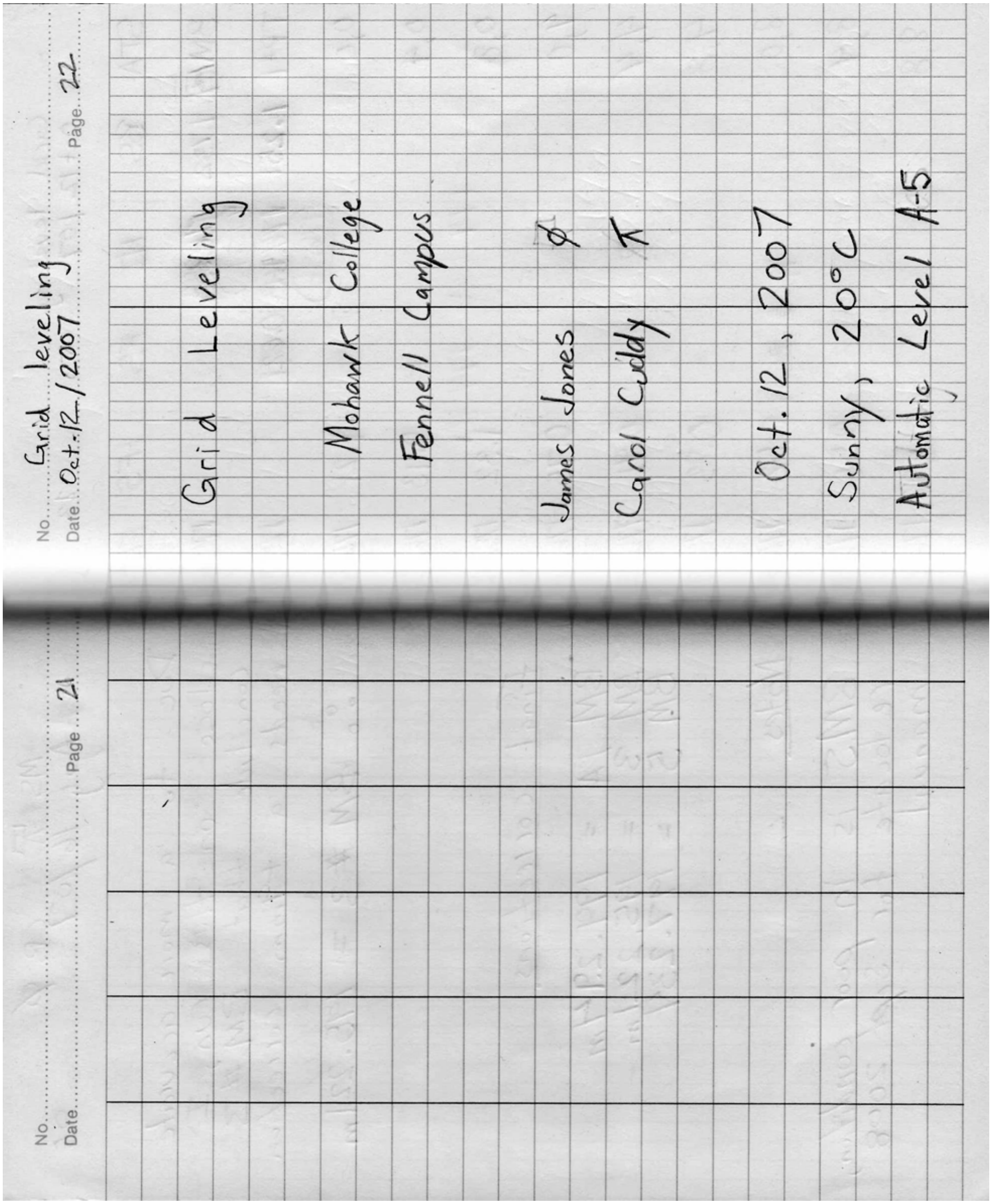
Allowable Error $= \pm 24\sqrt{K} = 24\sqrt{0.09}$
$= \pm 7mm$

$\therefore$ Closure Error < Allowable error

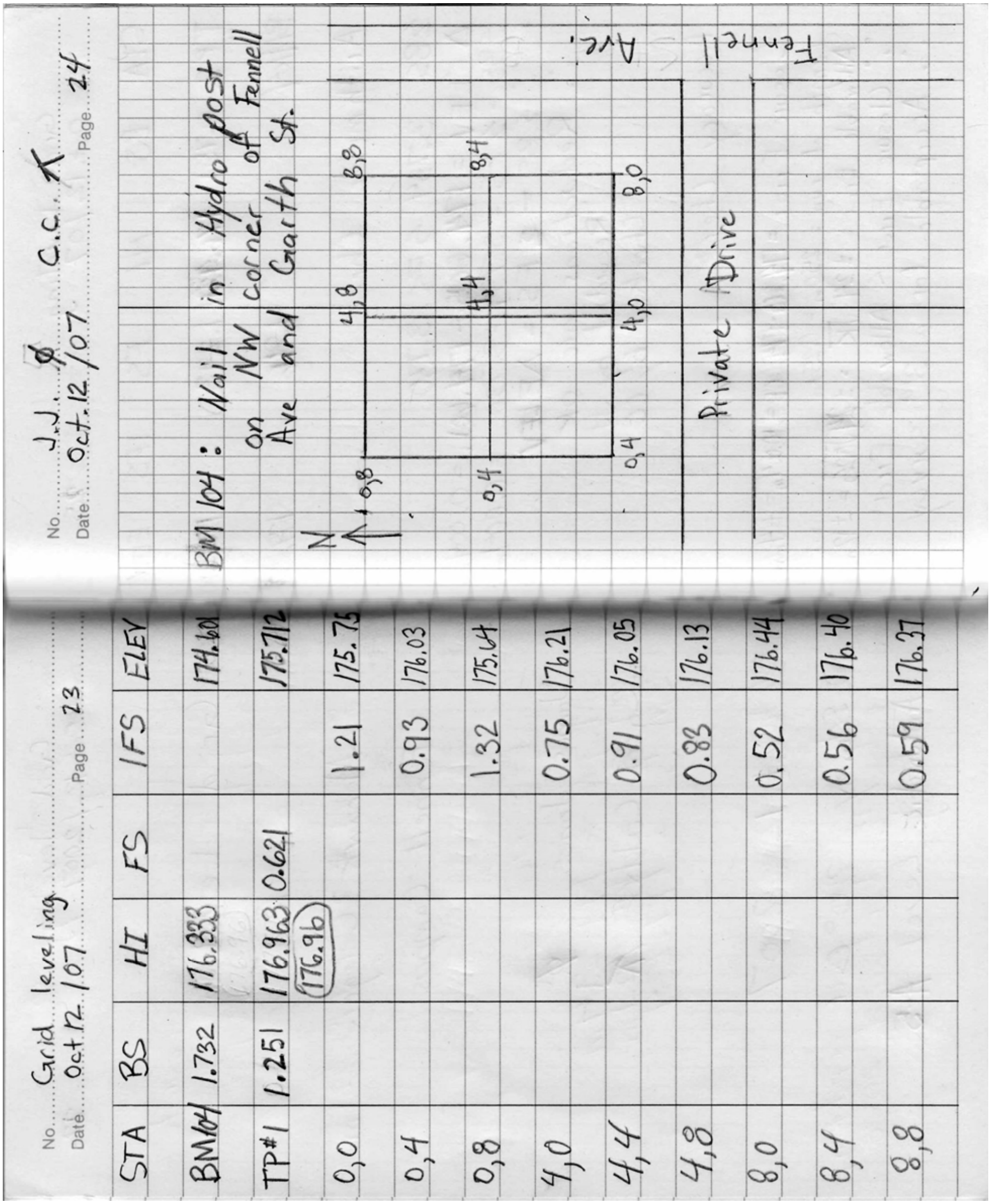
$\therefore$ Acceptable for 3rd order survey

No. J.J. C.C.
Date Oct 2, 2007 Page 20

Typical Profile Leveling Notes (continued)
Figure 2-S



Typical Grid Leveling Notes
Figure 2-T



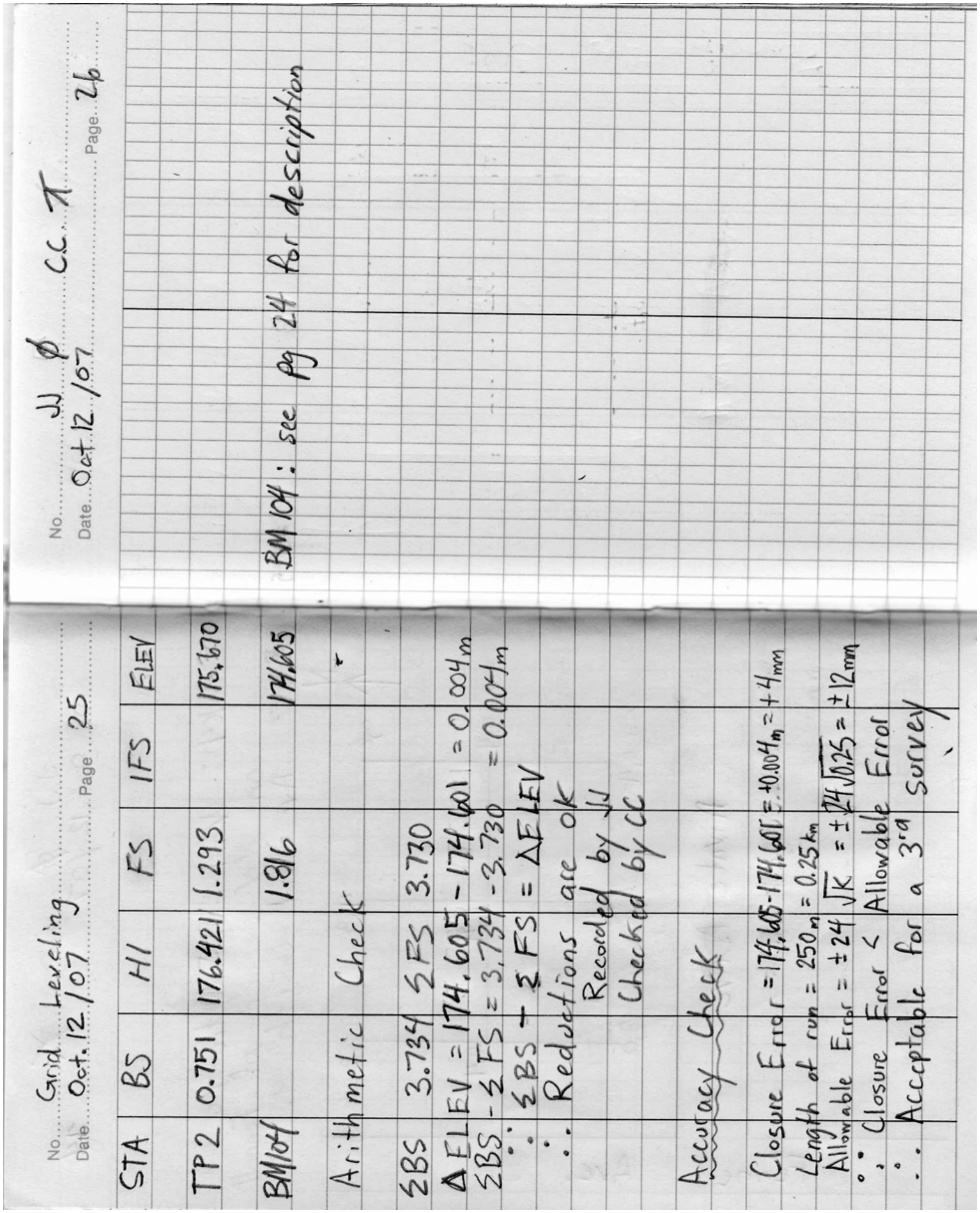
No. Grid leveling
Date Oct 12/07 Page 23

STA	BS	HI	FS	IFS	ELEV
BM104	1.732	176.333			174.601
TP#1	1.251	176.963 176.96	0.621		175.712
0,0				1.21	175.75
0,4				0.93	176.03
0,8				1.32	175.64
4,0				0.75	176.21
4,4				0.91	176.05
4,8				0.83	176.13
8,0				0.52	176.44
8,4				0.56	176.40
8,8				0.59	176.37

No. J.J. C.C.
Date Oct. 12/07 Page 24

BM 104 : Nail in Hydro post on NW corner of Fennell Ave and Garth St.

Typical Grid Leveling Notes (continued)
Figure 2-U



No. Grid Leveling
Date Oct. 12 /07 Page 25

STA	BS	HI	FS	IFS	ELEV
TP 2	0.751	176.421	1.293		175.670
BM104			1.816		174.605

Arithmetic Check

ΣBS 3.734 ΣFS 3.730

$\Delta ELEV = 174.605 - 174.601 = 0.004\,m$

$\Sigma BS - \Sigma FS = 3.734 - 3.730 = 0.004\,m$

$\therefore \Sigma BS - \Sigma FS = \Delta ELEV$

$\therefore$ Reductions are ok

Recorded by JJ

Checked by CC

Accuracy Check

Closure Error $= 174.605 - 174.601 = +0.004_m = +4_{mm}$

Length of run $= 250_m = 0.25_{km}$

Allowable Error $= \pm 24\sqrt{K} = \pm 24\sqrt{0.25} = \pm 12_{mm}$

$\because$ Closure Error < Allowable Error

$\therefore$ Acceptable for a 3rd survey

No. JJ ϕ CC π
Date Oct 12 /07 Page 26

BM 104 : see pg 24 for description

Typical Grid Leveling Notes (continued)

Figure 2-V

Obj. 2.7

Sources of Error in Leveling

Random

1. Natural causes: wind, moisture (fog up lenses), heat (heat waves in sight, unequal expansion of parts).

2. Excessive sight distance (> 90 m).

3. Rod not vertical.

4. Instrument motion caused by kicking, bumping, or clinging (i.e., too much "hands on").

5. Poor setup.

6. Rod not fully extended or clean on the bottom.

7. Failure to adjust for parallax: image of rod and cross hairs must both be in sharp focus.

Systematic

9. Instrument out of adjustment:

   - perform a "two-peg test" to check the instrument

   - keep the sight distances for the BS and FS equal

Blunders

10.
   - reading the rod incorrectly

   - recording the errors (e.g., transposing digits)

   - mixing up the BS and FS; reduce as you go!

Accuracy Requirement

The error of closure on a level circuit is the difference between the elevation of the final benchmark and the correct elevation. The magnitude of this error must not exceed the allowable error for the type of survey being conducted. For third order surveys, the allowable error is:

$\pm 24\sqrt{k}$ mm, where k is the distance along the leveling route in km.

Leveling Tips

Instrument Operator

1. Check rod visibility (tree branches, too high, too low).

2. Plan the setups, not only for visibility of the BS, but for the visibility of the FS also. The rod person must do the same when selecting the TP locations.

3. When taking a rod reading, read metres first, then decimetres, centimetres, and finally estimate millimetres. When the rod is waved the lowest numerical value is taken (ie. the rod is vertical).

4. Repeat the reading out loud, record it in the notes, re-read as a check; this will help to reduce errors such as reading 2.242 but recording 2.422.

5. After calculating the elevations or HI's, make a mental check to ensure that:

    - you didn't add when you should have subtracted,
    - the numbers look reasonable (have I been going uphill or downhill?)

6. Keep sight distances short (30 m to start, or approximately 30 to 40 paces) until you gain confidence in reading the rod. The maximum sight distance should be about 90 m. Also keep backsights and foresights at each set-up point approximately the same length to eliminate instrument error.

7. Read consistently: use the bottom or top of the horizontal cross hair; don't keep switching. DO NOT use the stadia marks (see Fig 2-G, page 17)

8. For a leveling circuit (i.e. BM #1 to BM #2 to BM #1), do an arithmetic check to prove the notes prior to starting the return run, and take the BS on BM #2 from a new setup.

9. Never rest your hands on or hold the tripod while taking a reading. Also, step back from the instrument when not taking a reading (i.e., avoid unnecessary contact). Protect it from passers-by.

Rod Person

10. Select a good spot for the TP:

    - pointed surfaces or edges are best

    - must be a hard surface, never grass or dirt!

    - mark with chalk (in case you make an error and have to backtrack)

11. Ensure that the bottom of the rod is free of ice, mud, etc., and that the rod is properly and securely extended.

12. Never lean the rod against a wall, lay it on the ground and never hold the rod upside down.

Obj. 2.8

In plane surveying all distances and horizontal angles are assumed to be projected onto a horizontal plane. Distances measured on a slope must usually be converted to horizontal distances.

Chainage or Stationing

Horizontal distances along a baseline

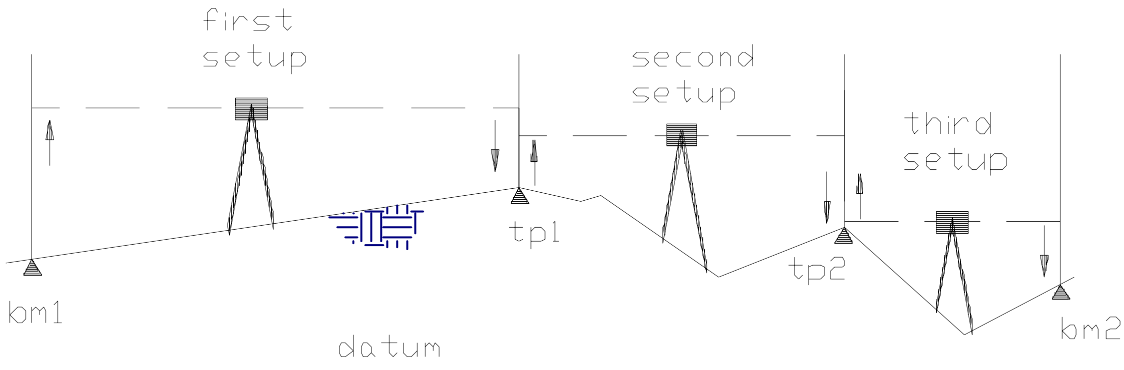
Metric:
- 1 station = 1 kilometre, start at station 0+000
- A station of 4+444.444 is located 4,444.444 metres along the baseline from the start at station 0+000

Imperial:
- 1 station = 100 feet, start at station 0+00
- A station of 4+44.44 is located 444.44 feet along the baseline from the start at station 0+00

Distances are taken at right angles to a base line (i.e., offsets) and are measured in metres or feet left (-) or right (+) of the centreline (while looking along the baseline in the direction of increasing chainage).

Example Questions & Answers

1. Prepare a set of level notes for the survey illustrated below. Show the arithmetic check. The elevation of bm1 is 195.582 m.



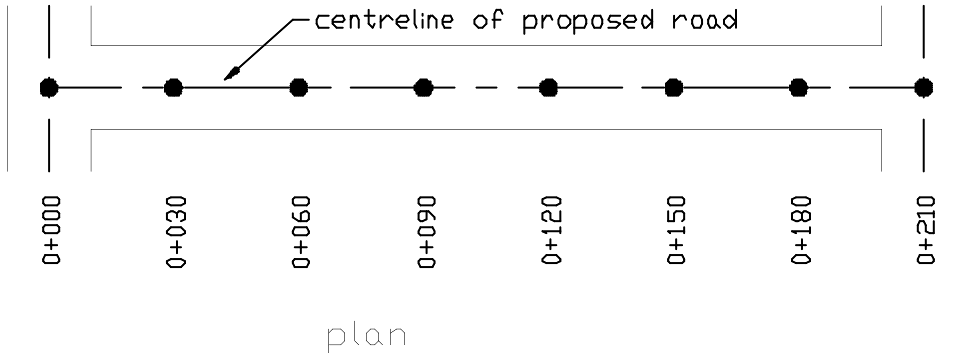
STA	BS	HI	FS	Elevation
BM #1	2.817	198.399		195.582 (given)
TP #1	0.982	197.902	1.479	196.920
TP #2	0.105	196.289	1.718	196.184
BM #2			0.428	195.861

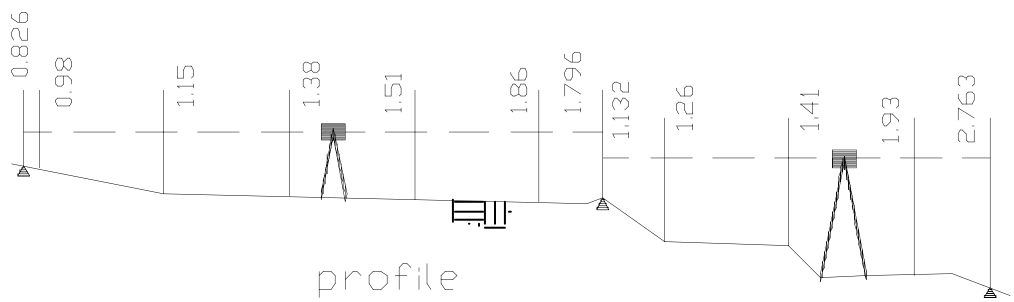
Sum of BS = 3.904
Sum of FS = 3.625
Sum of BS - Sum of FS = 3.904 - 3.625
= 0.279

Change in Elev = 195.861 - 195.582
= 0.279

Because, Sum of BS - Sum of FS = change in elev the reductions are correct.

2. Prepare a set of profile level notes for the survey illustrated below. Show the arithmetic check. The elevation of the benchmark is 100.000 m.





Profile Field Notes

STA	BS	HI	FS	IFS	Elevation
BM #1	0.826	100.826			100.000 (given)
		(100.83)			
0+000				0.98	99.85
0+030				1.15	99.68
0+060				1.38	99.45
0+090				1.51	99.32
0+120				1.86	98.97
TP #1	1.132	100.162	1.796		99.030
		(100.16)			
0+150				1.26	98.90
0+180				1.41	98.75
0+210				1.93	98.23
BM #2			2.763		97.399

Arithmetic Check

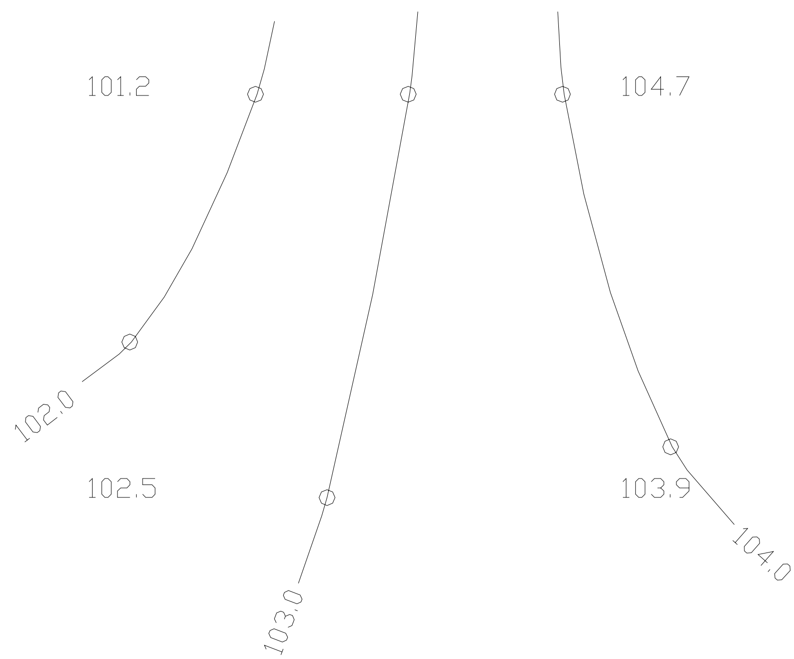
Sum of the BS	= 1.958		
Sum of the FS	= 4.559		
Sum of the BS – Sum of the FS		=	1.958 - 4.559
		=	-2.601
Change in Elev		=	97.399 - 100.000
		=	-2.601

Because, Sum of the BS – Sum of the FS = change in elev,
the reductions are correct.

When reducing profile field notes, do not reduce the elevations for IFS's until all HI's have been verified using the arithmetic check. If IFS's were read to 2 decimal places, the corresponding elevations calculated must also be to 2 decimal places (you can't make the elevations more precise than the readings). Note that the HI's that the IFS's were shot from have been rounded (in brackets) to the centimetre and the IFS's reduced (subtracted) from the rounded HI as mentioned above. Also note that the TP readings (to the millimetre) are reduced from the millimetre HI or elevation value.

Because horizontal distances are usually much greater than the elevation variations in the ground surface, it is usual to plot the vertical dimensions to a larger scale than that used for the horizontal distances. Typical scales for a profile drawing are: horizontal scale, 1:500; vertical scale 1:50. This exaggeration permits irregularities in the ground surface to be more readily apparent. In addition, if sewers or other utilities are plotted on the profile, the distances between them and the ground surface are seen clearly.

3. The plan shows spot elevations. The decimal point marks the location of the elevation. Draw the 102, 103, and 104 m contours. Determine the locations of the contours where they cross lines joining adjacent spot elevations by linear interpolation. Label the contours.

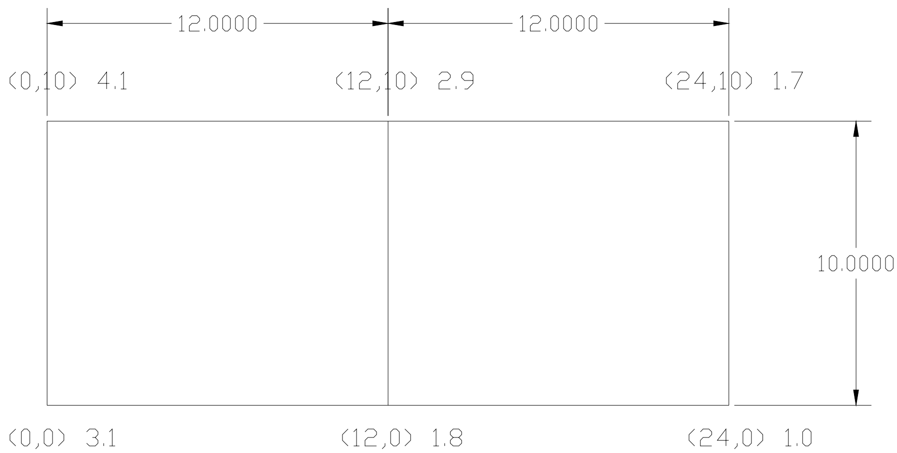


4. Three centreline grade stakes are placed at 10 m intervals and the tops of the stakes are surveyed and found to have elevations of 1) 98.30, 2) 98.40 and 3) 98.00. If the proposed grade at the first stake is 98.50 and the road is to slope down at a 2% grade what would be the cut and fill markings for each of the three stakes?

Proposed elevation at Stake 1 = 98.50
Proposed elevation at Stake 2 = 98.50 – 10x0.02 = 98.30
Proposed elevation at Stake 3 = 98.30 – 10x0.02 = 98.10
Or = 98.50 – 20x0.04 = 98.10 also

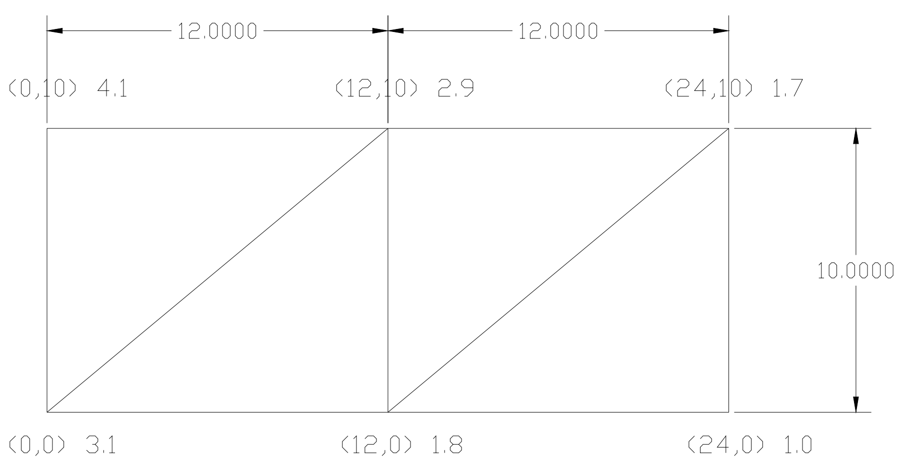
Stake 1: Proposed – Existing = 98.50 – 98.30 = +0.20 = Fill 0.20 m
Stake 2: Proposed – Existing = 98.30 – 98.40 = -0.10 = Cut 0.10 m
Stake 3: Proposed – Existing = 98.10 – 98.00 = +0.10 = Fill 0.10 m

5. The plan below shows a 12 by 10 m grid. The sides of the boundary are assumed to be vertical. The stations are identified by their co-ordinates. The number beside the co-ordinates is the depth of cut. Calculate the volume of cut using the rectangle method for spot elevations.



Volume of cut = sum of volumes of individual areas
= 0.25(4.1 + 2.9 + 1.8 + 3.1)(12 x 10)
+ 0.25(2.9 + 1.7 + 1.0 + 1.8)(12 x 10)
= 579 cubic metres

6. The plan below shows a 12 by 10 m grid. The sides of the boundary are assumed to be vertical. The stations are identified by their co-ordinates. The number beside the co-ordinates is the depth of cut. Calculate the volume of cut using the triangle method for spot elevations.



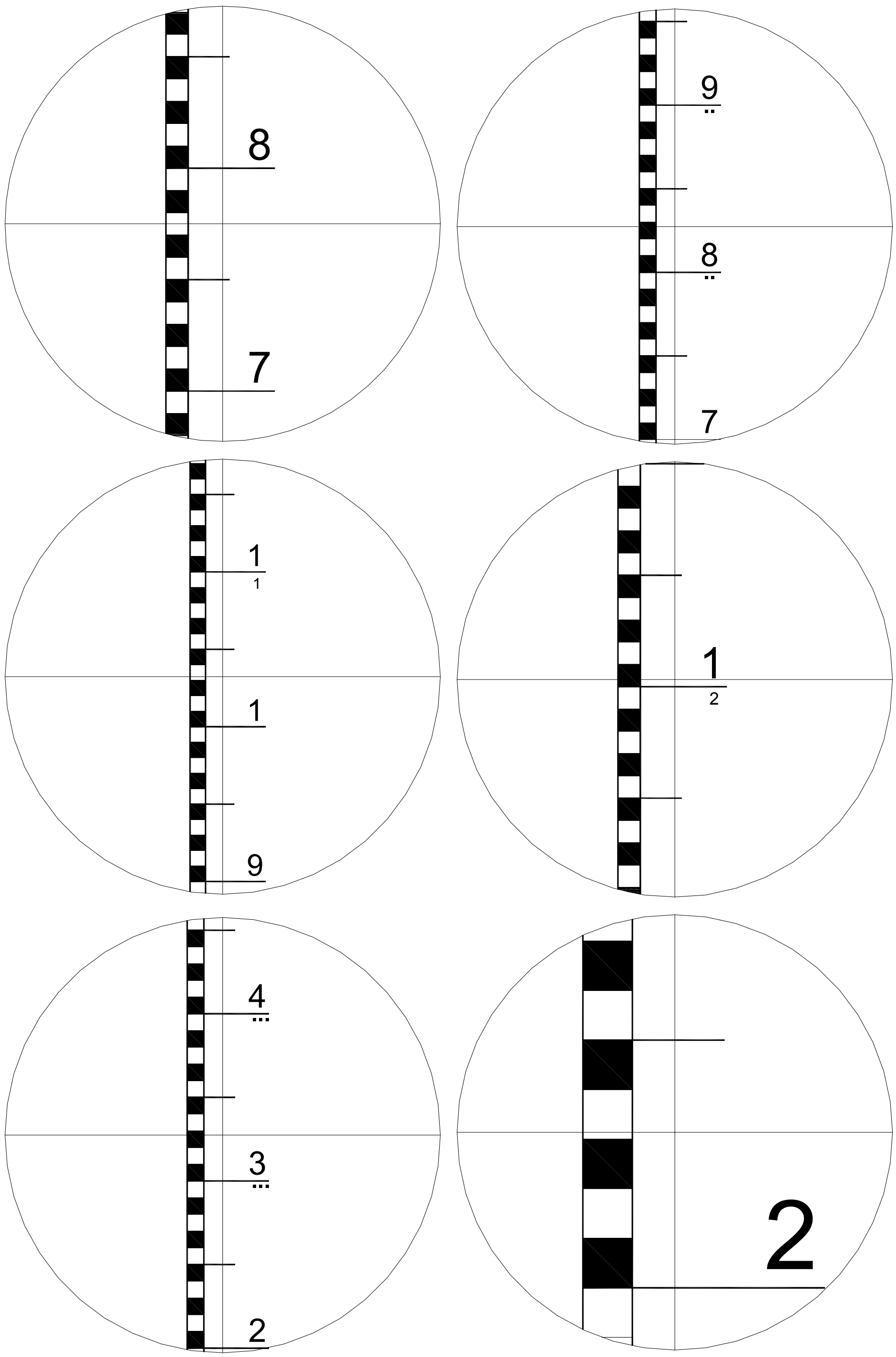
Station	Cut	Number of Triangles In which depth occurs	Product
0, 10	4.1	1	4.1
0, 0	3.1	2	6.2
12, 10	2.9	3	8.7
12, 0	1.8	3	5.4
24, 10	1.7	2	3.4
24, 0	1.0	1	1.0
	Totals	12	28.8

Average cut = 28.8/12 = 2.4 m

Volume of cut = average cut x total area
= 2.4 (24 x 10)
= 576 cubic metres

Problems

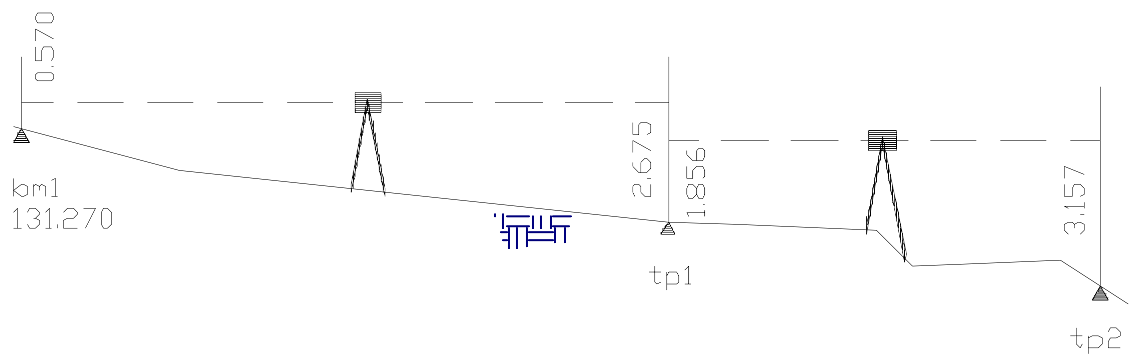
1. Determine the rod readings for the following diagrams.



2. Reduce the following field notes and perform the arithmetic check. If the actual elevation of BM #102 is 97.413 m and the total distance for this run was 810 m, is the closure error acceptable for a third order survey?

STA	BS	HI	FS	IFS	ELEV
BM #101	0.414				100.546
TP #1	1.521		1.844		
TP #2	1.157		1.594		
TP #3	0.747		1.528		
BH #102			1.944		

3. Prepare a set of level notes for the survey illustrated below. Show the arithmetic check. The elevation of the benchmark is 131.270 m.



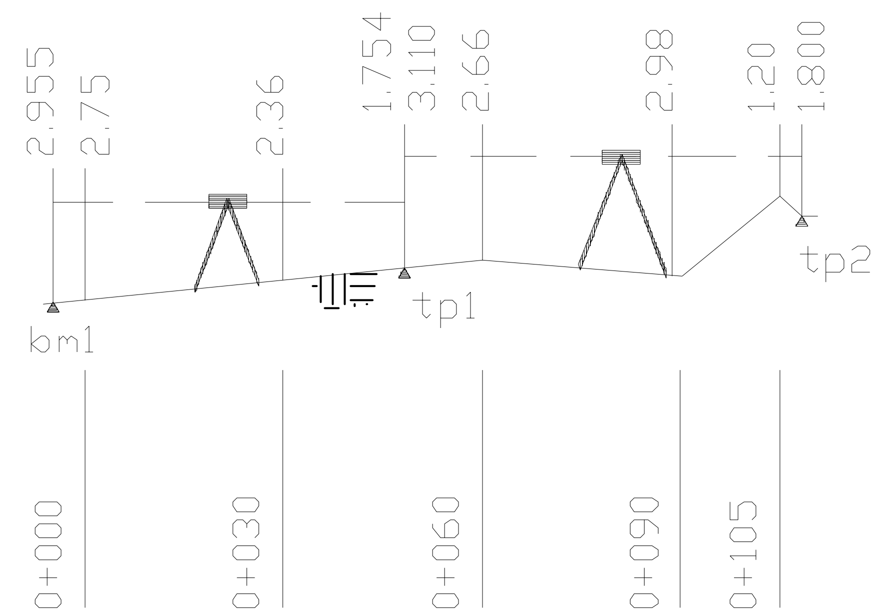
4. Given the bench mark leveling circuit readings and support data illustrated on page 49, Figure 2-W.

   1) Reduce the field notes,

   2) Perform the arithmetic check,

   3) Perform the accuracy check for a third order survey,

5. Prepare a set of profile leveling notes for the survey illustrated. The elevation of the benchmark is 472.660 m. The elevation of turning point 2 is 475.179 m. In addition to computing all the elevations, show the arithmetic check and the resulting error in closure. Is this acceptable for a third order survey?



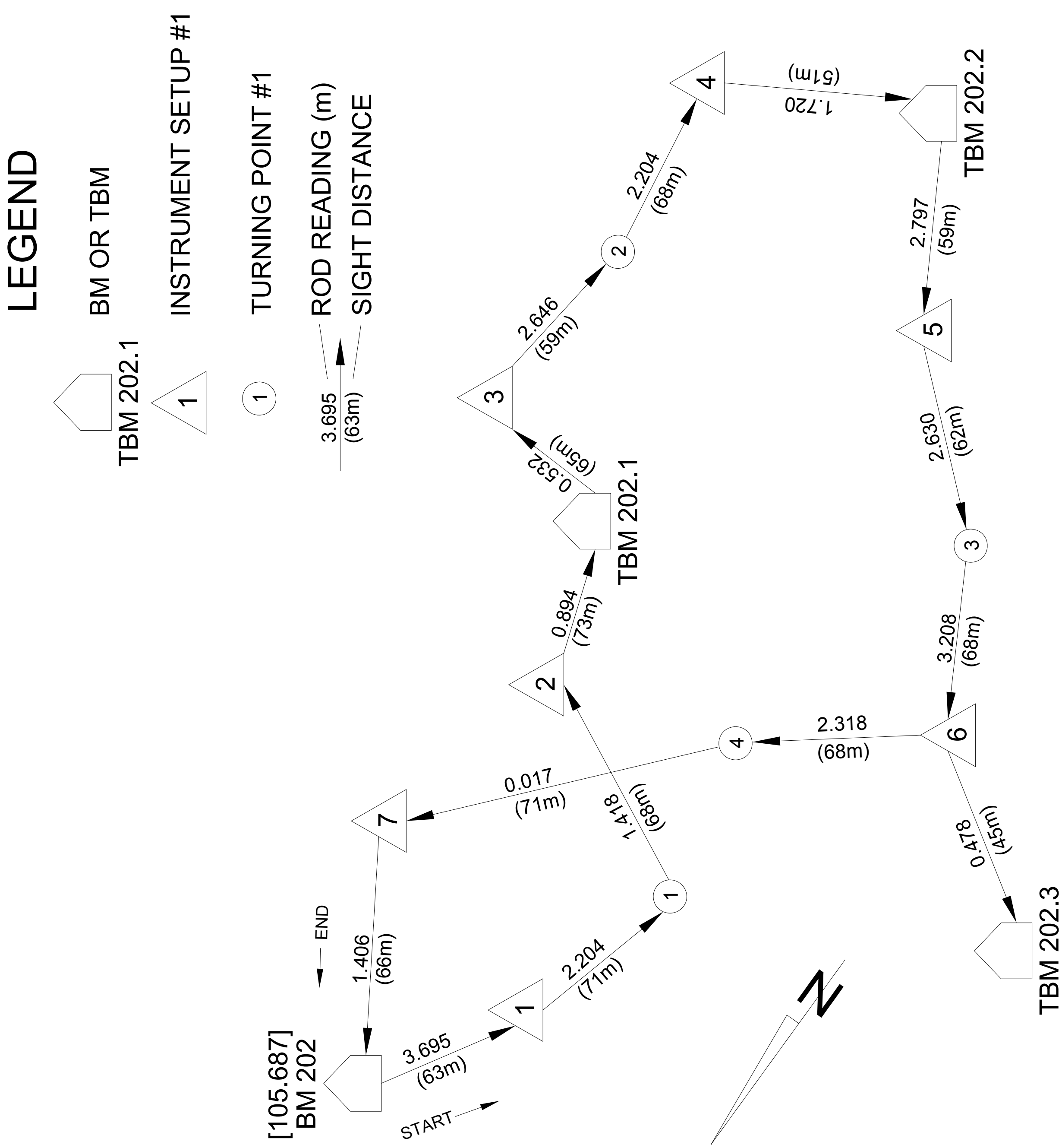
6. Given the centreline profile survey data (10-m intervals) for an existing road shown on page 50, Figure 2-X.

   1) Reduce the field notes,

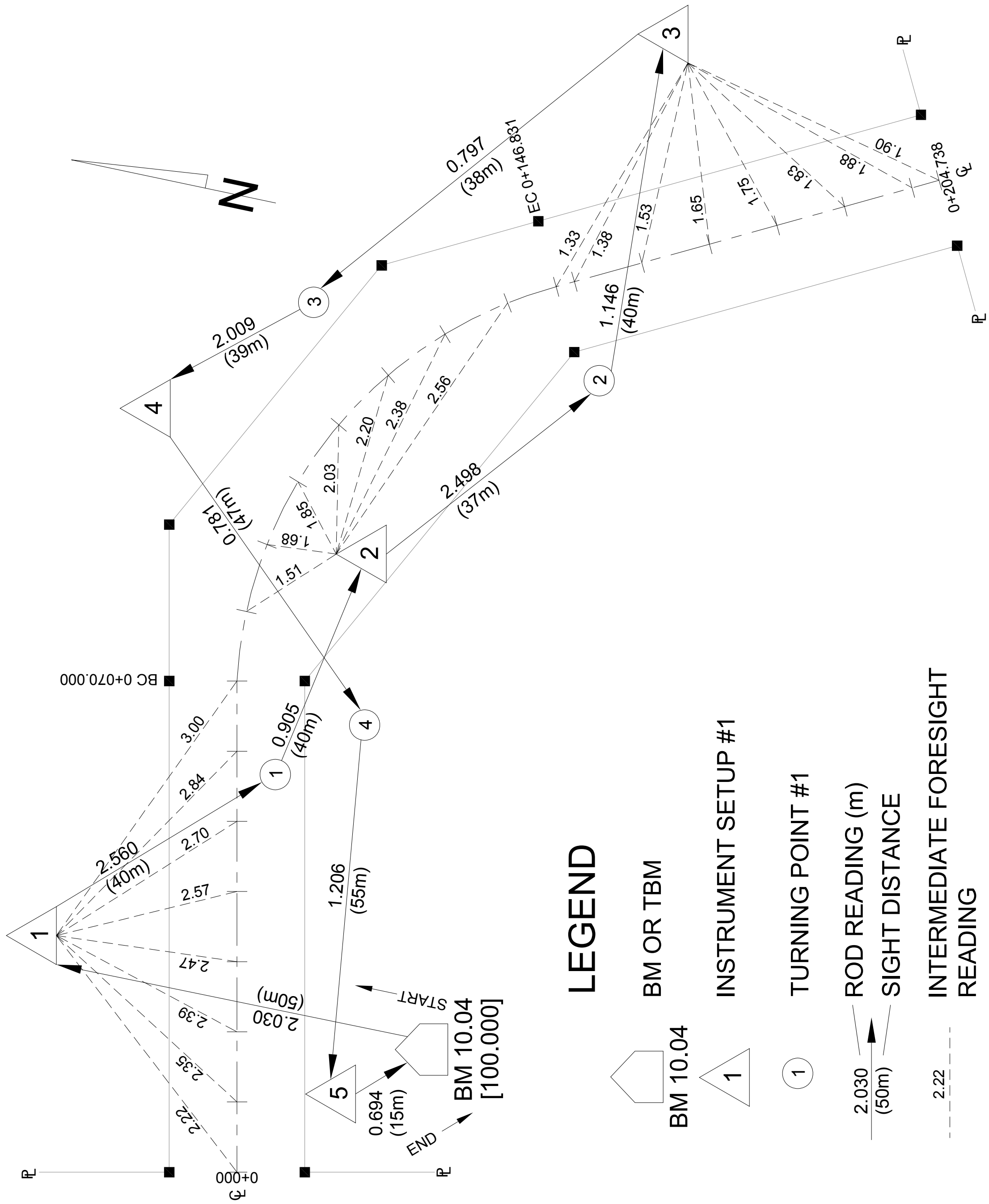
   2) Perform the arithmetic check,

   3) Perform the accuracy check for a third order survey,

   4) Plot the profile and determine the average percent grade over the horizontal curve, from BC to EC (note: % grade is defined in the direction of increasing stations).



Level Circuit Drawing for Question 4
Figure 2-W



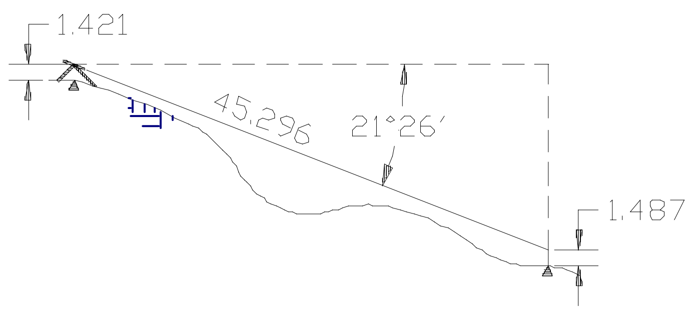
Road Centreline Profile Drawing for Question 6
Figure 2-X

7. The following readings were recorded in the order in which they were taken. Backsights and foresights were taken to three decimal places. Intermediate foresights were taken to two decimal places.

2.267, 2.509, 0.533, 0.726, 2.991, 1.29, 1.08, 0.96, 0.84, 2.637, 2.813, 1.966, 1.655, 2.417

The circuit began and ended on a benchmark with an elevation of 100.000 m. The average length of the backsights and foresights was 50 m. Record the data in field book form. Prove the notes. Determine if the error of closure is less +/- 24 mm $\sqrt{K}$ where K is the length of the circuit in km. The distance between the first intermediate point and the last intermediate point was 90 m. What's the slope of the line connecting these two points?

8. A pre-engineering baseline was run down a steep hill by measuring the vertical angle and the slope distance as shown below. The elevation of the station 1.421 m below the theodolite is 100.123 m. The chainage of this station is 0+564.212 m. Determine the elevation and chainage of the lower station.



9. The plan shows spot elevations. The decimal point marks the location of the elevation. Draw the 50, 50.5, 51, 51.5, and 52 m contours. Estimate their location. Label them.

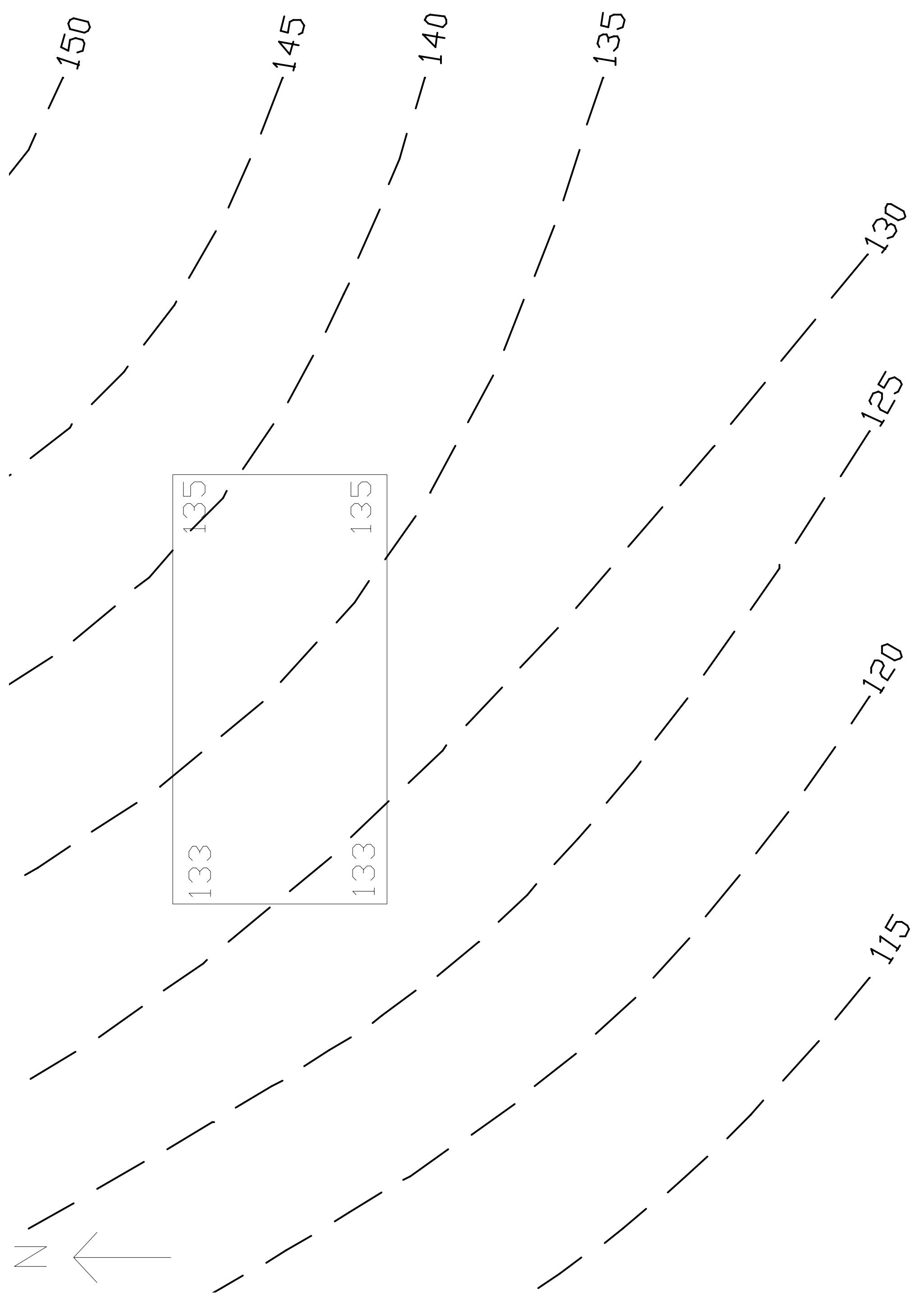
52.5	52.1	51.7	51.2
51.9	51.4	51.3	50.7
51.2	50.9	50.6	50.3
50.8	50.6	50.2	49.9

10. The plan shows spot elevations. The decimal point marks the location of the elevation. Draw the 25, 30, 35, 40, 45, and 50 m contours. Estimate their location. Label them.

35.0	37.0	42.0	49.0	53.0	50.0	47.0
33.0	36.0	38.0	42.0	47.0	46.0	43.0
29.0	31.0	33.0	35.0	39.0	41.0	44.0
20.0	25.0	27.0	34.0	41.0	45.0	48.0
28.0	31.0	32.0	35.0	39.0	44.0	46.0
36.0	38.0	37.0	36.0	37.0	38.0	41.0
38.0	39.0	40.0	41.0	43.0	45.0	46.0

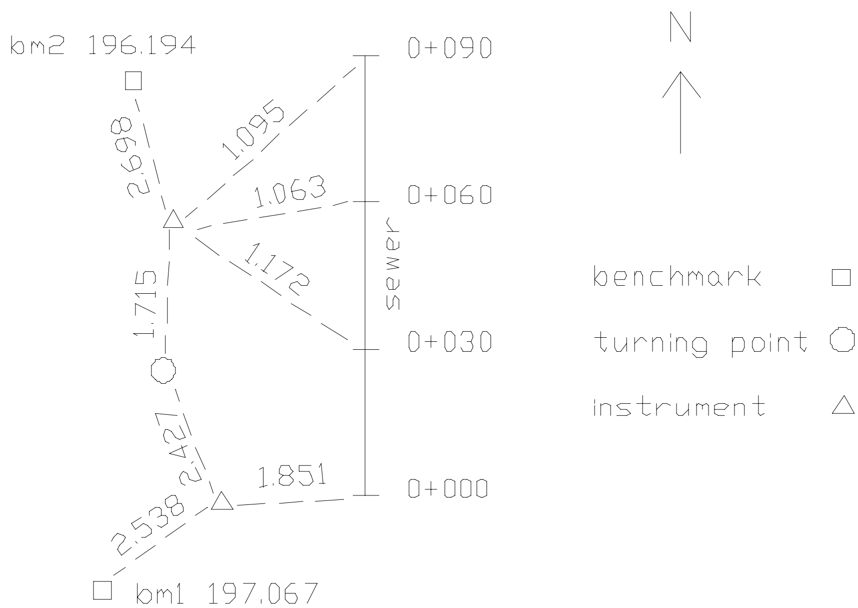
11. The plan below shows spot elevations. The ‘X’ marks the location of the elevation and GRD is a short form used to describe this as a ground shot. Draw contours at a 0.5m interval. Estimate their locations and label each contour.

12. The plan shows a proposed building site and the existing topography. The scale of the plan is 1:400. The proposed elevations at the corners of the site are shown. The site slopes uniformly in the east-west direction. Around the site, the slopes of the new ground surface are to be 3V:4H in fill areas, and 1V:1H in cut areas. Show the new contours to reflect this.



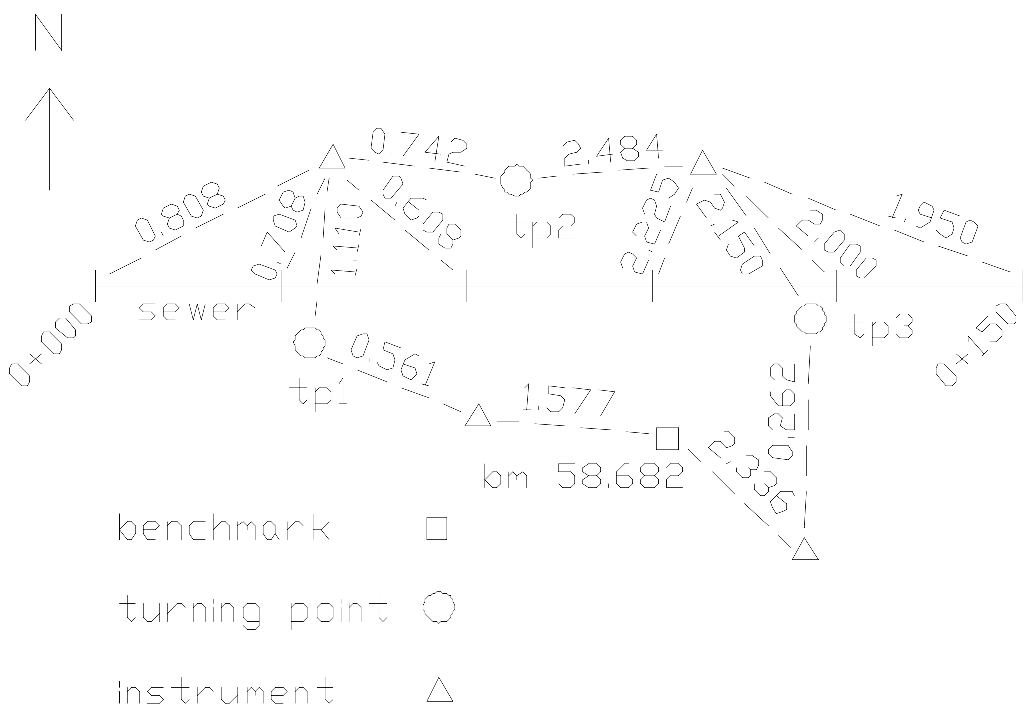
13. The plan shows the readings taken on grade stakes at stations 0+000, 0+030, … along the line of a sewer. Leveling started at bm1. The average length of the backsights and foresights was 30 m. Book the readings, reduce the levels, and prove the notes. Determine the error of closure. Determine the permissible error of closure using +/-24 mm $\sqrt{K}$ where K is the distance travelled (km). The invert elevation of the sewer at 0+000 is 194.800 m. The invert rises on a gradient of 0.5 percent from this point.

If a 4-m long grade (boning or sight) rod is used to determine the vertical alignment of the sewer invert, determine the distances from the grade stakes to the profile boards located at 0+000, 0+030, etc.

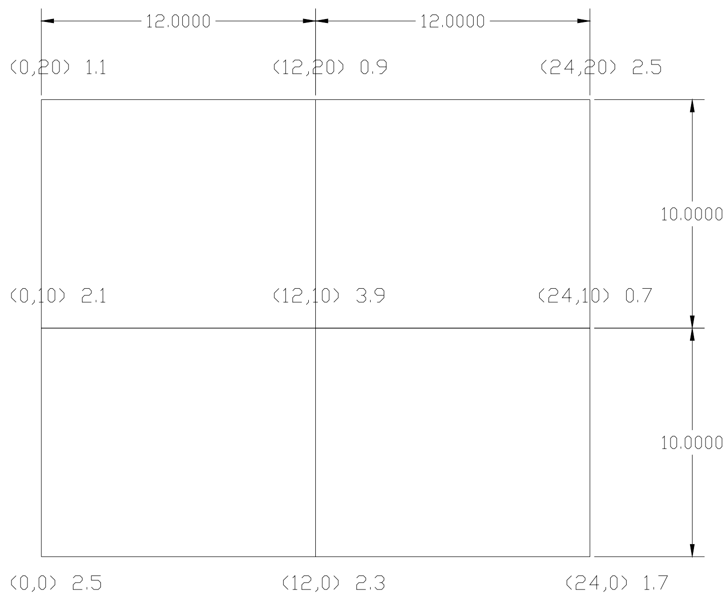


14. The plan shows the readings taken on profile boards at stations 0+000, 0+030, … along the line of a sewer. The numbering of the turning points gives the direction of leveling. The average length of the backsights and foresights was 45 m. Book the readings, reduce the levels, and prove the notes. Determine the error of closure. Determine the permissible error of closure using +/-24 mm $\sqrt{K}$ where K is the distance travelled (km). The invert elevation of the sewer at 0+000 is 56.000 m. The invert rises on a gradient of 0.333 percent from this point.

A 4-m sight rod is to be used to determine the vertical alignment of the invert. Some of the profile boards may have been disturbed. Determine which profile boards have been disturbed, and determine the error (mm high or low).



15. The plan below shows a 12 by 10 m grid. The sides of the boundary are assumed to be vertical. The stations are identified by their co-ordinates. The number beside the co-ordinates is the depth of cut. Calculate the volume of cut using the rectangle method for spot elevations.



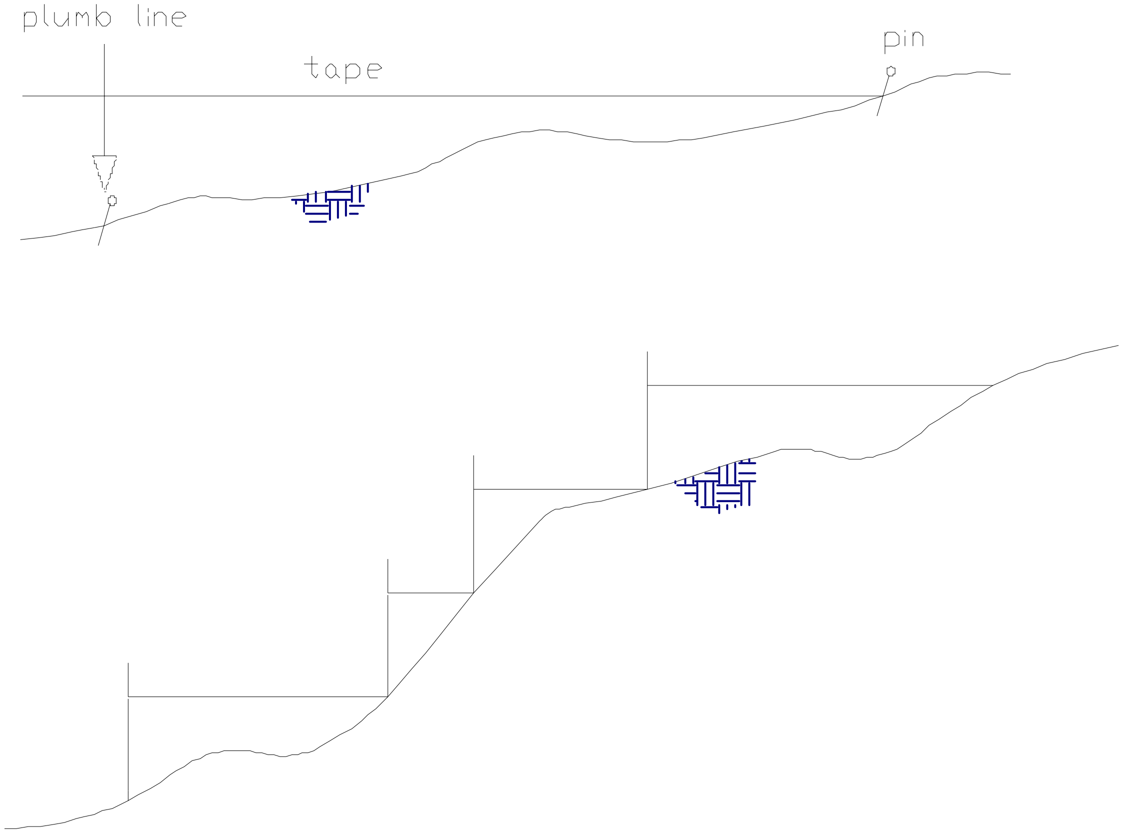
16. Repeat question 13 using the triangle method for spot elevations.

SURVEYING SURV EA141 / CV104
MODULE 3: DISTANCE MEASUREMENT

In surveying, the measurement of distance is the second requirement in the collection of spatial information. By distance we mean horizontal and sloping distances as opposed to the measurement of vertical distance (elevation) which was covered in Module 2. Techniques for collecting distance information include the very simple to the technically complex. Depending upon the situation each can be a useful part of surveying.

Obj #	Learning Objective	Resources
3.1	What are four methods of obtaining distance measurements? When is each appropriate to use?	Lecture/bb.mohawkcollege.ca Ref. Text 1
3.2	What kinds of tapes are used in measuring distance? What are their characteristics?	Lecture/bb.mohawkcollege.ca Ref. Text 1
3.3	Describe how a distance should be measured when using a tape.	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 3-A & Class Notes
3.4	What types of error can occur in distance measurement? What techniques are used to minimize such errors?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Class Notes
3.5	Define a "horizontal distance". How can one calculate such a distance from non horizontal measurements?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Example Questions 1, 2 & 3
3.6	How does an EDM work? What equipment is required?	Lecture/bb.mohawkcollege.ca Ref. Text 1
3.7	How is distance information recorded?	Lecture/bb.mohawkcollege.ca Figure 3-B
3.8	Example Questions and Answers	
3.9	Problems	

Obj 3.3



Procedure for Measuring Horizontal Distance with a Tape
Figure 3-A

Obj 3.4

There is a set of standard conditions for measurement using a steel tape. They are;

1. Temperature, 20° C (68° F)
2. Tape fully supported throughout
3. Under a tension of 50 N (10 pound-force)

All conditions must be met for accurate measurement. Even if these conditions are met certain errors can occur.

Taping Errors can be systematic or random as outlined below;

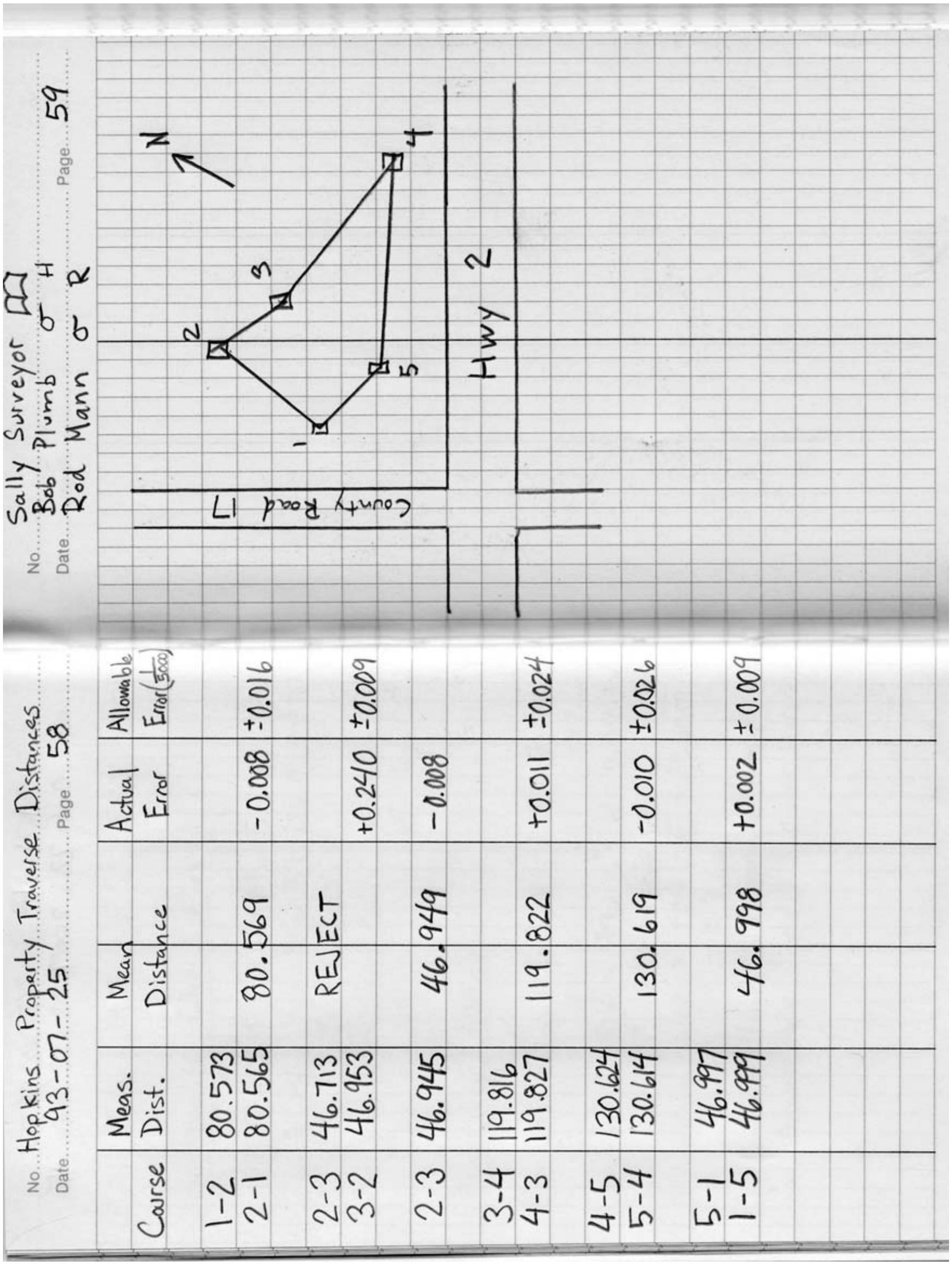
Systematic	Random
1. erroneous tape length	1. misreading tape
2. tension	2. losing a pin (1 tape length)
3. sag	3. tape not horizontal
4. temperature	4. tape (or plumb bob) not on the mark
5. slope	5. misalignment

The temperature corrections to be applied to non-standard temperature distances measured with a steel tape are given below:

System Of Units	Temperature Correction, Ct	Units
Imperial	(6.45 x 10-6) x (T - 68°) x L	ft.
Metric	(1.16 x 10-5) x (T - 20°) x L	m

where T = temperature at the time of measurement (°)
L = distance measured (or to be laid out)

Obj. 3.7



No. Hopkins Property Traverse Distances
Date 93-07-25 Page 58

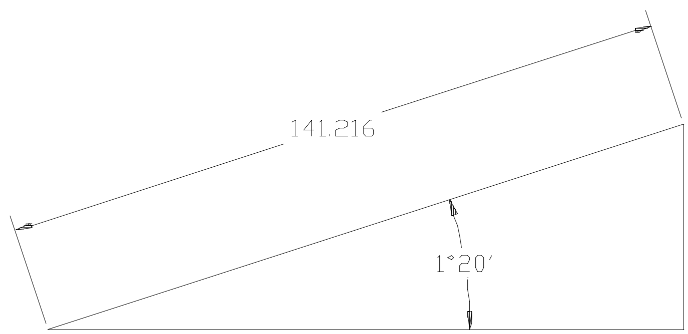
Course	Meas. Dist.	Mean Distance	Actual Error	Allowable Error (1/5000)
1-2	80.573			
2-1	80.565	80.569	-0.008	±0.016
2-3	46.713	REJECT		
3-2	46.953		+0.240	±0.009
2-3	46.945	46.949	-0.008	
3-4	119.816			
4-3	119.827	119.822	+0.011	±0.024
4-5	130.624			
5-4	130.614	130.619	-0.010	±0.026
5-1	46.997			
1-5	46.999	46.998	+0.002	±0.009

No. Sally Surveyor
Bob Plumb ♂ H
Date Rod Mann ♂ R
Page 59

Distance Measurement Notes
Figure 3-B

Example Questions and Answers

1. A distance of 141.216 m is measured along a slope angle of 1° 20'. Calculate the horizontal distance.

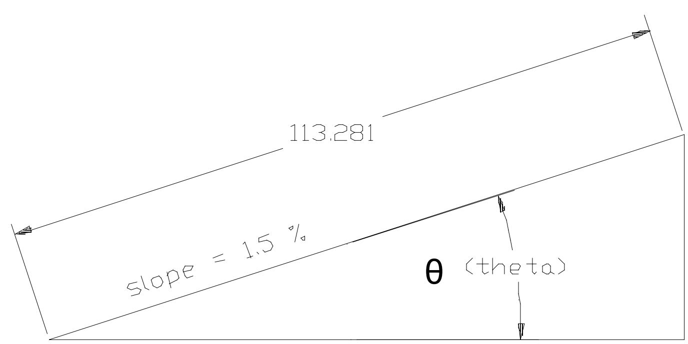


$$\cos(1°20') = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{\text{horizontal dist}}{\text{slope dist}}$$

thus,

horizontal dist	=	slope dist x cos(1° 20')
	=	141.216 x cos(1° 20')
	=	141.178 m

2. A distance of 113.281 is measured along a slope gradient of 1.5%. Calculate the horizontal distance.



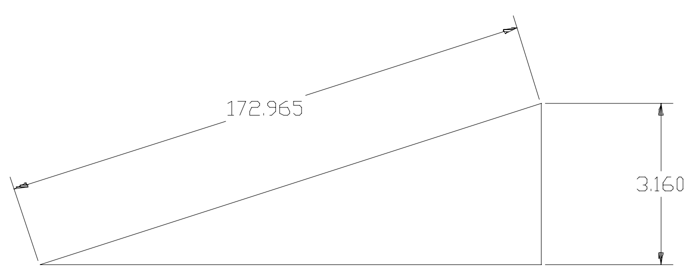
$$\tan = \frac{\text{opposite}}{\text{adjacent}}$$
$$\tan = \frac{1.5}{100}$$
$$\theta = \tan^{-1}(0.015)$$
$$\theta = 0.8593722^\circ$$

Horizontal dist	=	slope dist x cos
	=	113.281 x cos(0.8593722°)
	=	113.268 m

or,

$$\frac{\text{horizontal dist}}{113.281} = \frac{100}{\sqrt{(100^2 + 1.5^2)}}$$

3. A distance of 172.965 is measured along a slope with a elevation difference of 3.160 m. Calculate the horizontal distance.



slope dist^2	=	horizontal dist^2 + vertical dist^2
horizontal dist^2	=	$172.965^2 - 3.160^2$
	=	29906.9056
horizontal dist	=	$\sqrt{29906.9056}$
	=	172.936 m

Problems

1. The slope measurement between two points is 41.236 m and the slope angle is 1° 18'. Determine the horizontal distance.

2. The slope distance between two points is 841.894 m and the slope angle is 3°51’10”. Calculate the horizontal distance

3. A distance of 101.970 m. was measured along a 2% slope. Determine the horizontal distance.

4. A slope distance of 34.803 m was recorded on a 6% grade. Calculate the horizontal distance.

5. The slope distance between two points is 72.777 m and the difference in elevation is 1.33 m. Determine the horizontal distance.

6. The slope distance measured between two points was recorded as 30.038 m. The elevation at point 1 is 195.330 m and the elevation at point 2 is 196.850 m. Calculate the horizontal distance.

7. It is required to set a point (B) on the ground at the top of an earth berm with 3:1 side slopes. The horizontal distance from a point, A at the base of the berm to the required point B at the top is 60.000 m. What slope distance should be measured?

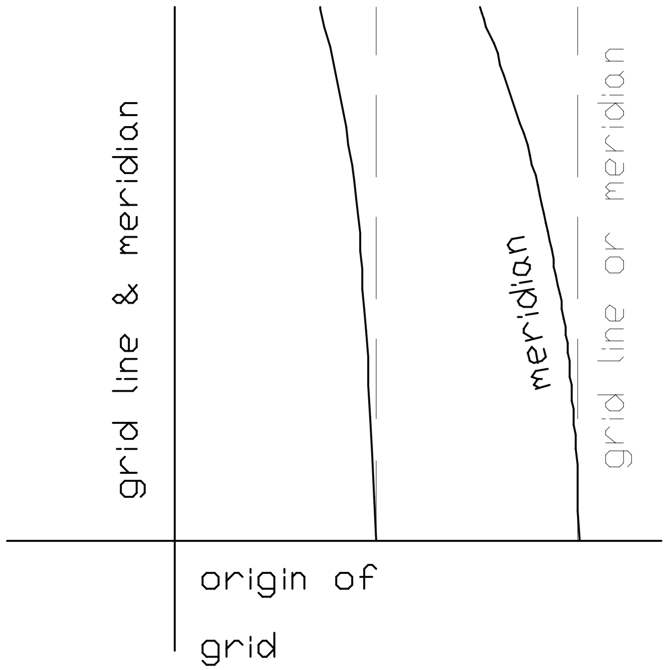
8. The elevation of station 1+380 on a road centreline is 186.213 m ASL. It is desired to lay out a station 1+560 on the road centreline to mark the start of a NO PASSING zone. If the centreline of the pavement is falling at a constant 3.5% grade between the two stations:
    a. What slope distance must be measured to layout station 1+560?
    b. What should the elevation of station 1+560 be?

SURVEYING SURV EA141 / CV104
MODULE 4: THE DIRECTION OF A LINE

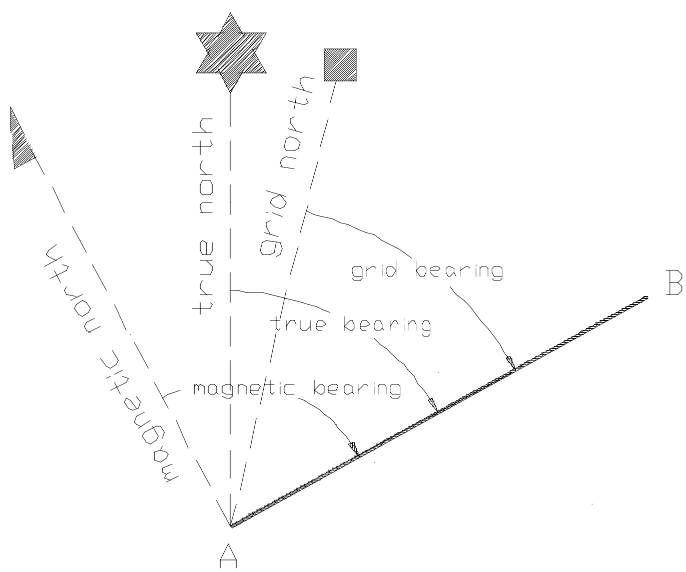
Horizontal distances in surveying, ie vectors, are defined by their magnitude and direction. This module covers the direction of horizontal distances. Direction is expressed as a bearing or as an azimuth. Bearings and azimuths involve the measurement and setting out of horizontal angles. Horizontal angles are measured and set out in three ways; clockwise, counter clockwise and deflection. The deflection angle is the angle a survey line makes with the preceding line produced beyond the station occupied; it may be to the left or to the right.

Obj #	Learning Objective	Resources
4.1	What is a "meridian"? What role does it play with respect to measuring angles in surveying?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figures 4-A & 4-B
4.2	What methods are used to specify the size of an angle? What units are commonly used in surveying?	Lecture/bb.mohawkcollege.ca Ref. Text 1
4.3	What is an "azimuth". What is a "back azimuth"? How are they calculated?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 4-C
4.4	What is a "bearing". What is a "back bearing"? How are they calculated?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 4-C
4.5	What is the relationship between azimuths and bearings? How do you convert from one to the other?	Lecture/bb.mohawkcollege.ca Ref. Text 1
4.6	What is meant by "magnetic declination"? Why is this an important concept in surveying?	Lecture/bb.mohawkcollege.ca Ref. Text 1
4.7	Define a traverse. What types of traverses exist? How are traverses used in surveying?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figures 4-D & 4-E
4.8	What is the significance of an "occupied point"? How is an instrument set up over a point?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 4-F
4.9	What is a "polar co-ordinate"? How is it expressed?	Lecture/bb.mohawkcollege.ca Ref. Text 1
4.10	What is a "rectangular co-ordinate"? How is it expressed?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 4-G
4.11	Example Questions and Answers	
4.12	Problems	

Obj. 4.1

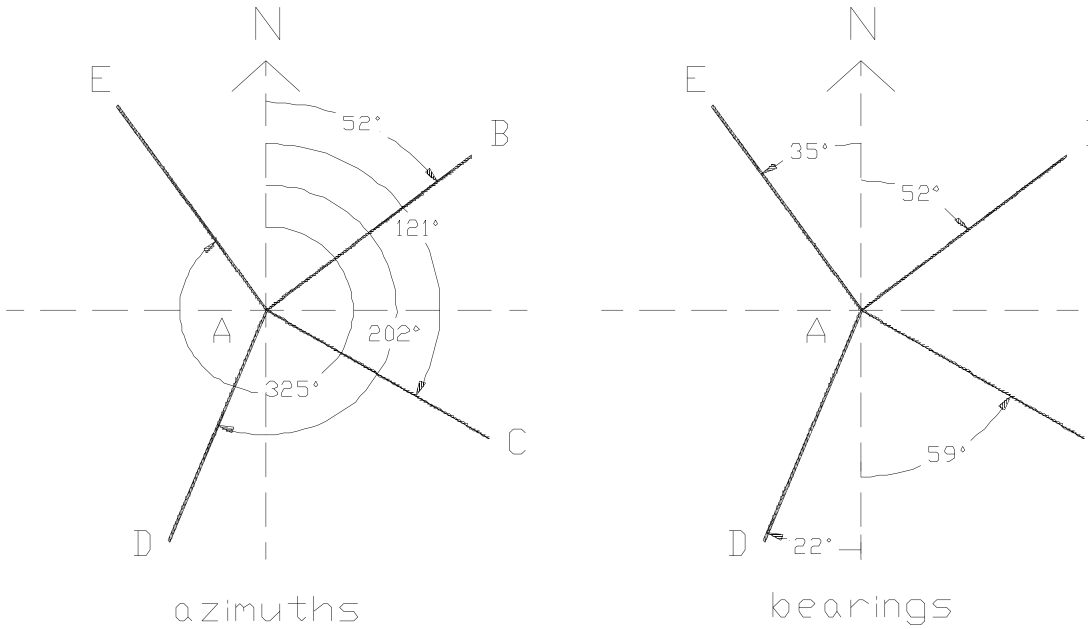


Relationship Between Grid Meridians and True Meridians
Figure 4-A



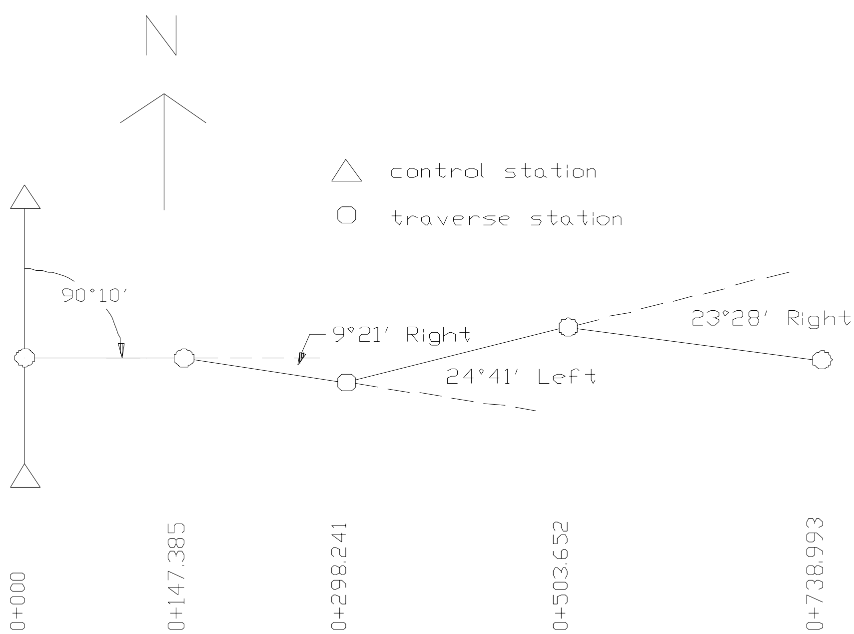
Magnetic, True and Grid Meridians
Figure 4-B

Obj. 4.3, 4.4 & 4.5

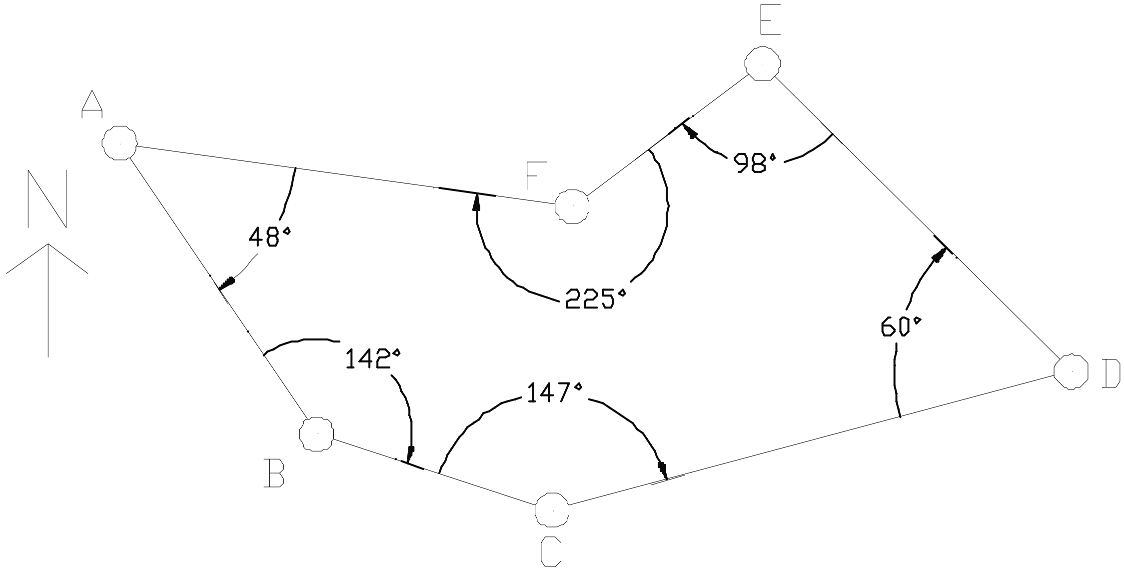


Azimuths and Bearings
Figure 4-C

Obj. 4.7



Open Traverse
Figure 4-D



Closed Traverse
Figure 4-E

Obj. 4.8

Setting up an instrument over a point

NOTE: See the "How to set up over a point" video in the help topics section of the online learning space (bb.mohawkcollege.ca).

1. Before starting the set-up, ensure that the foot screws are all approximately at mid-adjustment and that the instrument is at the centre of the tripod plate.

2. Position the instrument over the point so that the tripod plate is reasonably level and the point is visible in the optical plummet, say within 5 mm.

3. Step in the legs firmly.

4. Centre the cross-hairs of the optical plummet over the point using the leveling screws.

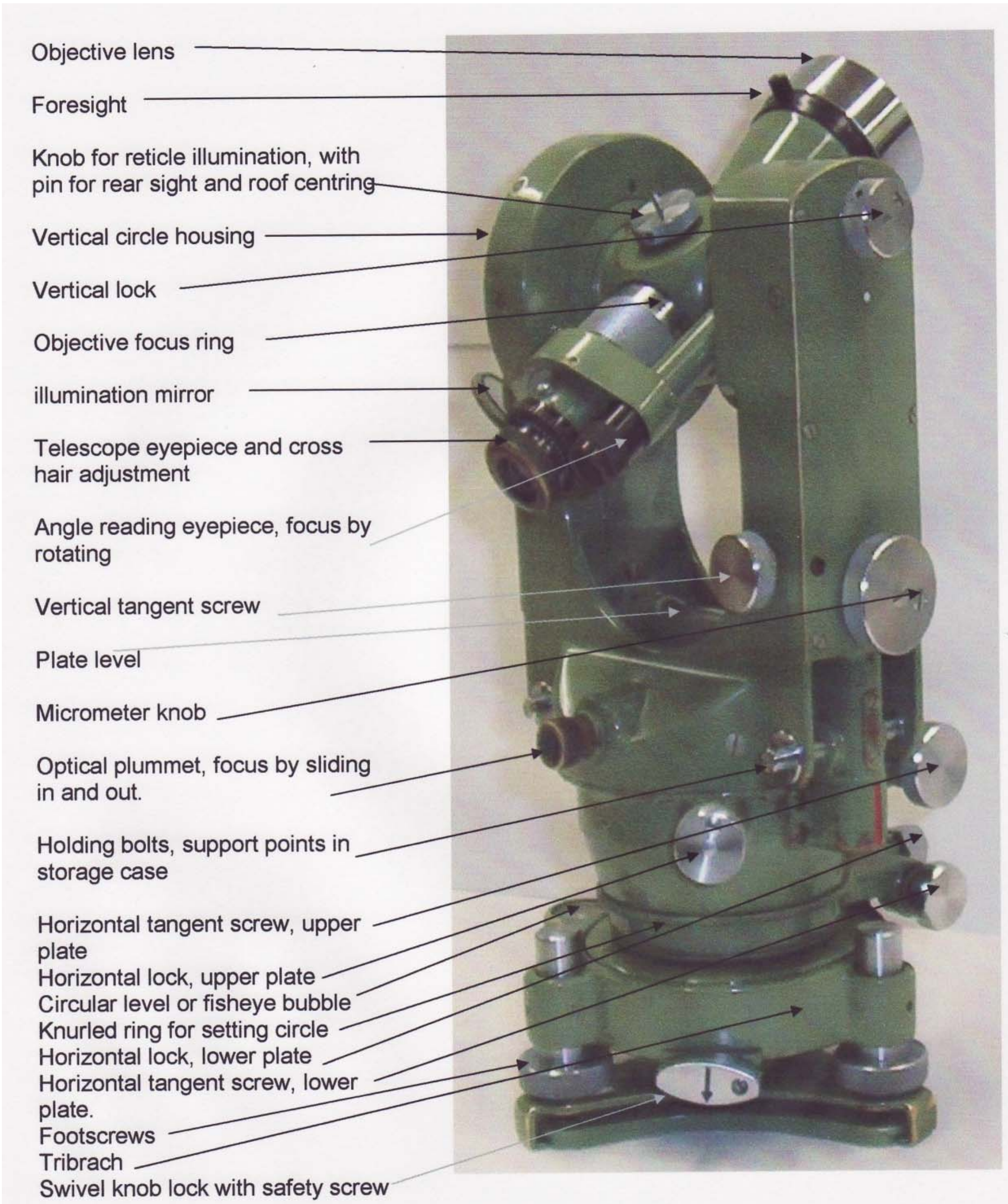
5. Centre the circular level (bull's eye or fish eye bubble) by adjusting the length of the legs.

6. Level the plate level, first in one direction, and then in a direction perpendicular to the first.

7. Check the centering of the optical plummet. If it is off, re-centre the crosshairs by loosening the tripod attachment bolt and sliding the instrument in the X-Y direction (don't rotate it). Remember to re-tighten the tripod bolt.

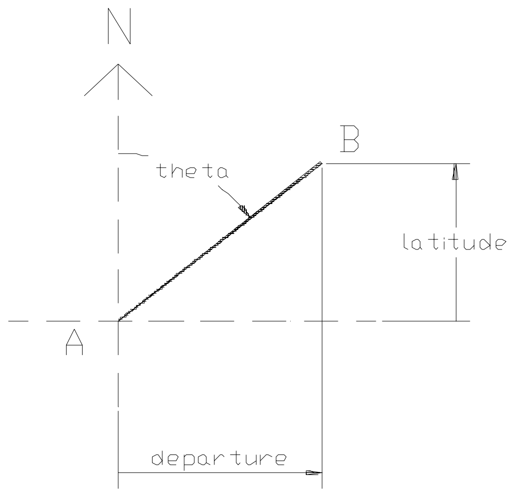
8. Check the plate level. If it is off, repeat steps #6 and #7 until the instrument is level, over the point, and firmly stepped into the ground.

The Wild T1-A is rarely used in the field anymore, but it sets up over a point in the same fashion as any total station. This is the instrument used in the instrument testing held at the end of the semester. On the next page is a list of parts of the T1-A.



Wild T1-A list of parts
Figure 4-F

Obj. 4.10

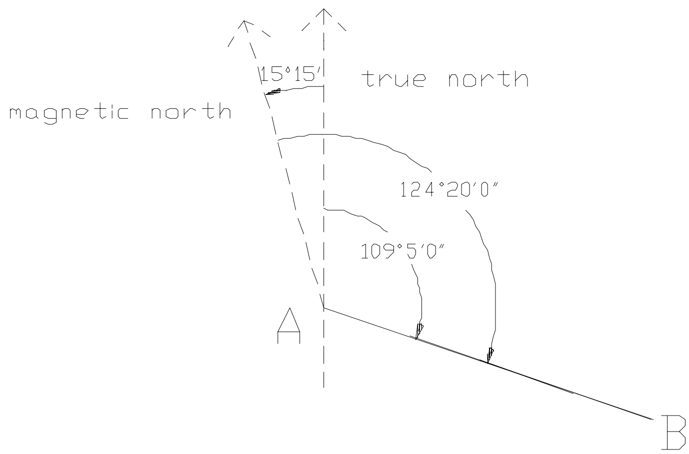


Rectangular Coordinates
Figure 4-G

Example Questions and Answers

1. If the magnetic declination for a particular area is 15° 15' W and the magnetic azimuth is 124° 20', find the true azimuth.

Draw the true meridian and draw the magnetic meridian which is 15° 15' west of true north. Then draw the magnetic azimuth 124° 20' clockwise from the magnetic meridian. The true azimuth is then equal to 124° 20' - 15° 15' = 109° 05'



2. If two of the interior angles of a three-sided traverse are equal to 45° 27' 00" and 50° 52' 30" what is the value of the third angle?

   Theoretical sum of angles of a looped traverse is 180°(n-2), where n is the number of sides. Therefore the angles should equal 180°(3-2) = 180°(1) = 180°.

   180° 00' 00"
   - 45° 27' 00"
   <u>- 50° 52' 30"</u>
   83° 40' 30"

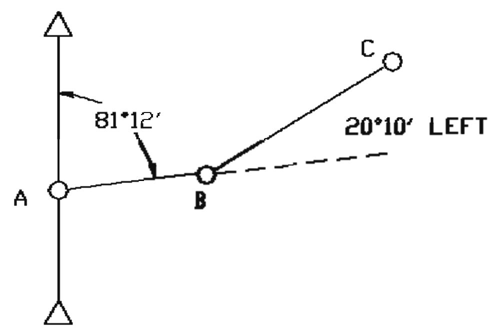
3. What bearing is equal to an azimuth of 178° 19' 25"? What is the back azimuth (reverse azimuth) of 178° 19' 25"?

   An azimuth of 178° 19' 25" lies in the south east quadrant. Therefore the angle for the bearing is calculated as 180° - a = 180° - 178° 19' 25" = 1° 40' 35". Therefore the bearing is S 1° 40' 35" E.
   Because the azimuth is less than 180° we add 180° to calculate the back azimuth. So the back azimuth is 178° 19' 25" + 180° 00' 00" = 358° 19' 25".

4. What azimuth is equal to a bearing of N58° 45' 20"W? What is the back bearing (reverse bearing) of N58° 45' 20"W?

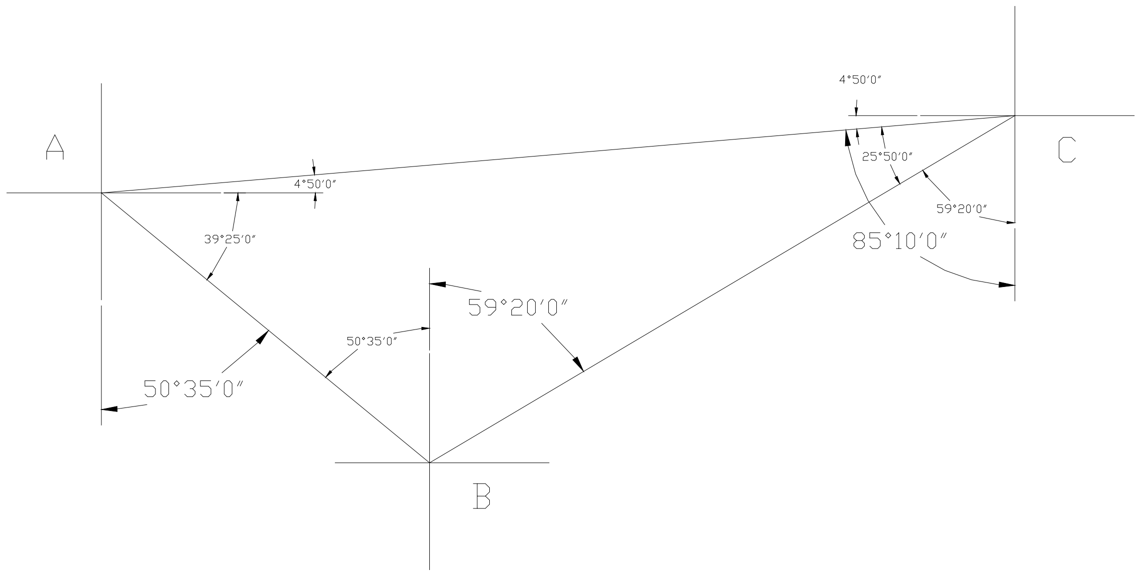
   The bearing lies in the north west quadrant. Therefore the equivalent azimuth is calculated as 360° - a where a is the bearing angle. Therefore the azimuth equals 360° - 58° 45' 20" = 301° 14' 40".
   To calculate the back bearing the angle stays the same but the quadrant is reversed. Therefore the back bearing would equal S58° 45' 20"E.

5. If the bearing of a line AB is N 81°12'E and the deflection angle of line BC is left 20°10', what would be the bearing of line BC?



If the bearing of AB is N 81°12'E then the angle the line makes with the reference (grid) meridian is 81°12'. This is true of the dotted extension of line AB also. If we deflect from this line to the left by an amount of 20°10' then we are reducing the original bearing angle by 20°10' (81°12' - 20°10' = 61°2'). The bearing of line BC would therefore be N61°2'E.

6. If the bearings of a looped traverse ABC are; AB; S50°35'E, BC; N59°20'E and CA; S85°10'W, determine the interior angles.



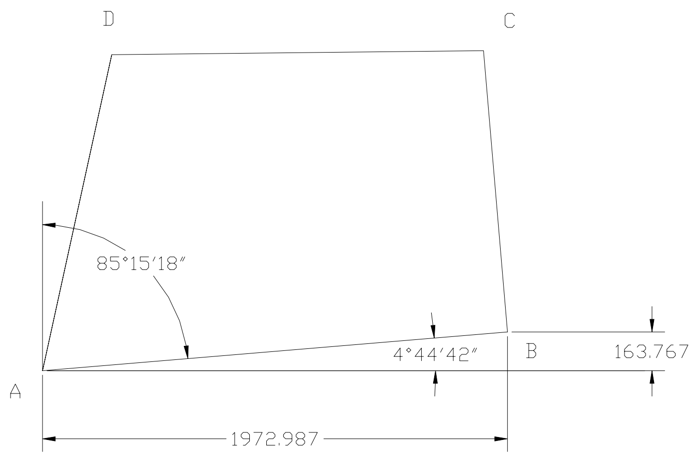
Check the angles geometrically.
The lines AB, BC and CA are drawn using the bearings given and are indicated by the large size angle readings. Using the alternate angle theorem the angle of 50°35' can be calculated at B and the angle of 59°20' can be calculated at C (both shown by the small size angle readings). The interior angle of 25°50' at C (shown in small print) can be calculated as 85°10' - 59°20' = 25°50'. The angle of 4°50' at C is calculated from 90°00' - 85°10' = 4°50'. This angle of 4°50' can also be transferred to A by the alternate angle theorem. Finally the angle of 39°25' at A is calculated from 90°00' - 50°35' = 39°25'. This gives all the necessary information to be able to calculate the interior angles at A, B and C by adding the components as follows;

Angle A = 4°50' + 39°25'	=	44°15'
Angle B = 50°35' + 59°20' =	=	109°55'
Angle C	=	25°50'
Total	=	180°00'

This total is correct because the sum of the interior angles should equal 180°(3-2) = 180°(1) = 180°.

7. If a four-sided traverse has the following station co-ordinates calculate the distance and bearing of each side.

Station	Northing (m)	Easting (m)
A	728.086	1199.405
B	891.853	3172.392
C	2083.398	3070.634
D	2066.456	1493.375



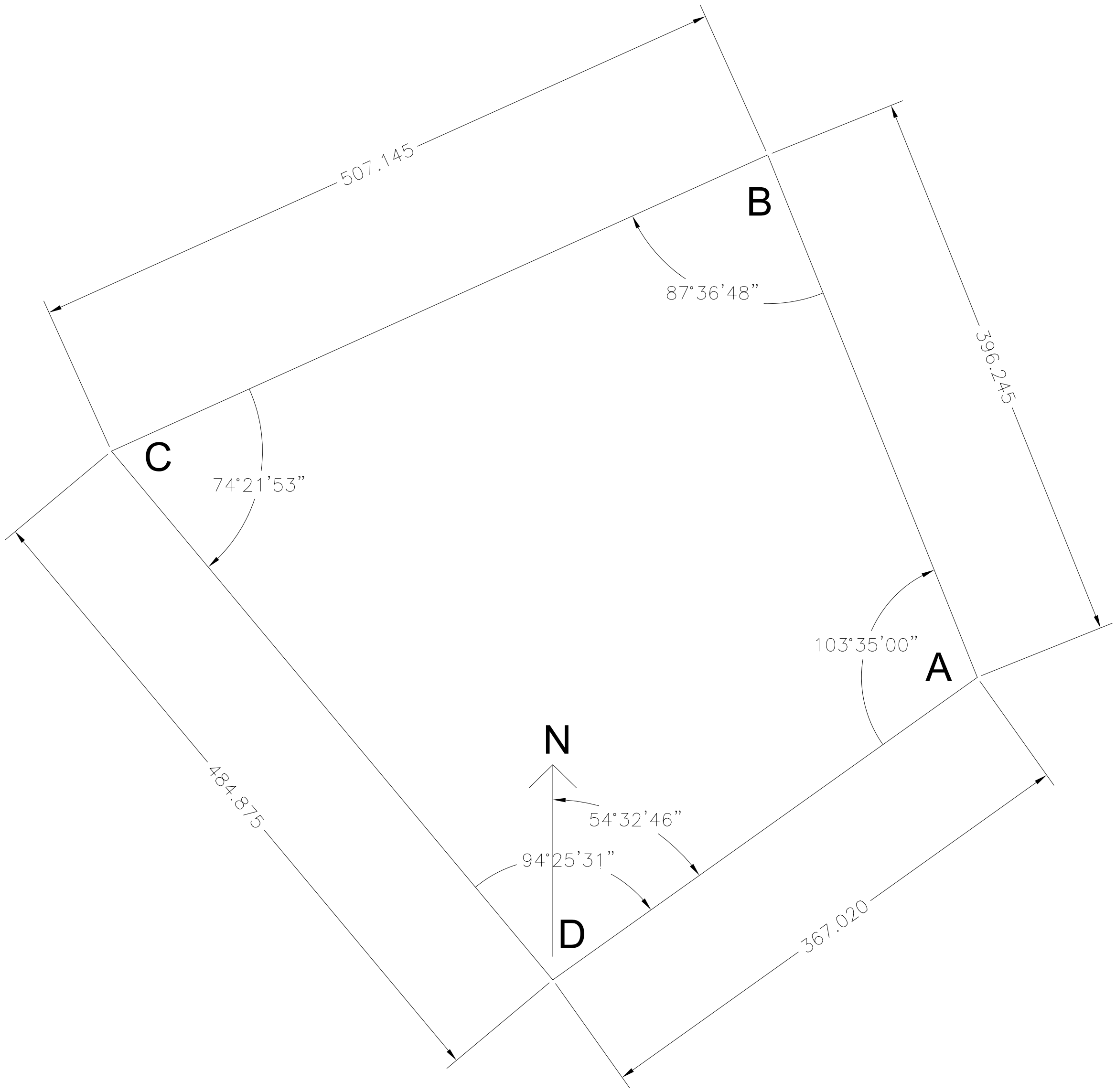
Using the northings (y co-ordinates) and eastings (x co-ordinates) for points A and B we can calculate the distance between A and B in the x and y directions as shown on the diagram above. From this information the inverse tan function can be used to calculate the angle between AB and the horizontal distance. $\tan^{-1}\left(\frac{163.767}{1972.987}\right) = 4°44'42''$

If we subtract this angle from 90° we will have the angle that line AB makes with the reference meridian. This is equal to 90° 00' 00" - 4° 44' 42" = 85° 15' 18". So the bearing of line AB is N 85° 15' 18" E. The length of line AB can be calculated using the pythagorean theorem. $\sqrt{1972.987^2 + 163.767^2} = 1979.772\text{m}$. The bearings and lengths of the other sides can be solved for in the same way with the following results;

BC	N 4° 52' 52" W	1195.882 m
CD	S 89° 23' 5" W	1577.350 m
DA	S 12° 23' 17" W	1370.275 m

Traverse Calculation Example

A four sided closed traverse



Step #1

Make a diagram, keeping in mind that this is a counterclockwise solution and that all interior angles are turning to the right.

Given: Azimuth D-A = 54°32'46" (or Bearing D-A = N 54°32'46" E)
Coordinates of Station D (5000,5000)
Measured Course D-A = 367.020m
Measured Course A-B = 396.245m
Measured Course B-C = 507.145m
Measured Course C-D = 484.875m

Step #2

Check and adjust the interior angles measured in the field (Field angles). The sum of the interior angles for any traverse should equal 180°(n-2), where n equals the number of sides. Therefore, the sum of the angles should equal 180°(4-2) = 360°. If our angles do not add up to 360° even, the error is equally distributed to all the interior angles. Let's put our results in a tabular form.

Station	Field Angle	Adjustment	Adjusted Angle
A	103°35'00"	+12"	103°35'12"
B	87°36'48"	+12"	87°37'00"
C	74°21'53"	+12"	74°22'05"
D	94°25'31"	+12"	94°25'43"
Sums	359°59'12"	+48"	360°00'00"

Angular error of closure $= 359°59'12" - 360°$

$= -48"$

adjustment/angle $= \dfrac{-(-48")}{4}$

$= +12"/\text{angle}$

Step #3

Given the azimuth of one course (ie: D-A), find the azimuth of the other courses, proceeding counterclockwise. Use the adjusted interior angles from step #2 to calculate the results. Use the diagram to keep yourself oriented when following through these calculations below.

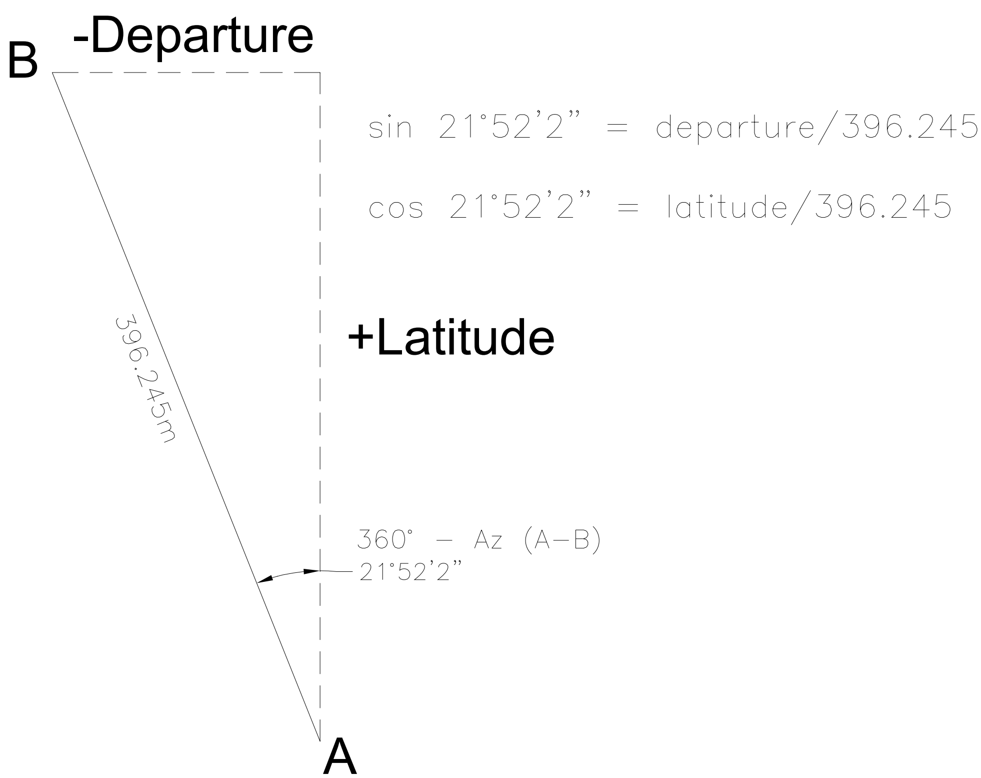
Az (D-A)	=	54°32'46"	(given data)
	+	180°	(to find the back Az (D-A) which is Az (A-D))
Az (A-D)	=	234°32'46"	
+ angle A	+	103°35'12"	(add the interior angle to get the Az (A-B))
Az (A-B)	=	338°07'58"	
	-	180°	(to find the back Az (A-B) which is the Az (B-A))
Az (B-A)	=	158°07'58"	
+ angle B	+	87°37'00"	(add the interior angle to get the Az (B-C))
Az (B-C)	=	245°44'58"	
	-	180°	(to find the back Az (B-C) which is the Az (C-B))
Az (C-B)	=	65°44'58"	
+ angle C	+	74°22'05"	(add the interior angle to get the Az (C-D))
Az (C-D)	=	140°07'03"	
	+	180°	(to find the back Az (C-D) which is the Az (D-C))
Az (D-C)	=	320°07'03"	
+ angle D	+	94°25'43"	(add the interior angle to get the Az (D-A))
Az (D-A)	=	414°32'46"	
	-	360°	(because an azimuth cannot exceed 360°)
Az (D-A)	=	54°32'46"	(agrees with the initial azimuth)

Step #4

Calculate the latitudes and departures using the azimuths from step #3 and measured field distances given in step #1.

If the survey was 100% perfect, the sum of the latitudes and departures would each add up to zero. There is error in this survey, so let's determine the amount of error by starting with the calculation of latitudes and departures. NOTE: record latitudes and departure to at least 4 decimals places here to avoid round off error in steps to come.

Example: Latitude and Departure from station A to B

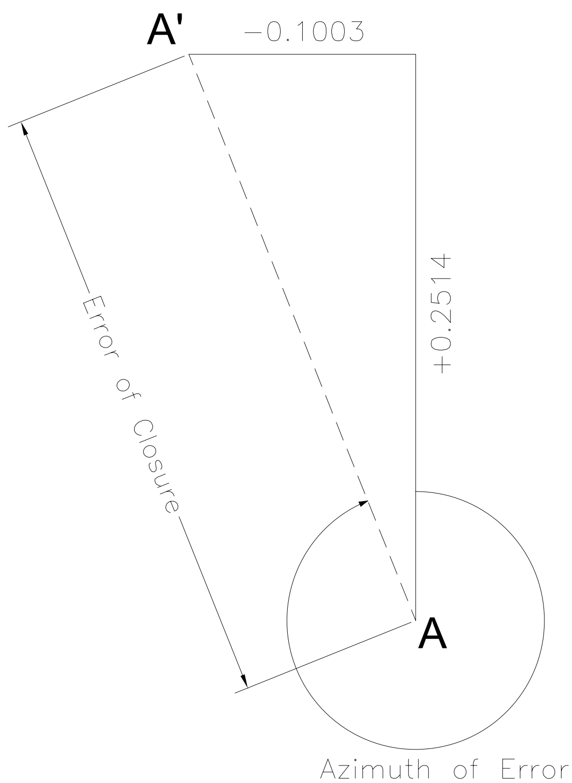


Station	Azimuth	Distance	Latitude	Departure
A				
	338°07'58"	396.245	+367.7350	-147.5842
B				
	245°44'58"	507.145	-208.2985	-462.3935
C				
	140°07'03"	484.875	-372.0742	+310.9093
D				
	54°32'46"	367.020	+212.8891	+298.9681
A				
	Total	1755.285	+0.2514	-0.1003

Step #5

Determine the error of closure, azimuth of error and accuracy ratio.

As stated in step #4, we know this survey is not 100% perfect. According to the calculations of latitudes and departures, if we start at station A and return back to station A with the azimuths and distances we currently have we would not return to the same spot. The difference is calculated by summing up both the latitudes and departures as done in step #4. We would end up 0.2514m north and 0.1003m west of where we started as station A (these are the errors in latitude and departure respectively) (see diagram below).



The error of closure is the distance of A to A' which is calculated using theorem of Pythagoras as follows:

Error of Closure = $\sqrt{0.2514^2 + 0.1003^2}$

= 0.27067m

Azimuth of error = 360° - angle A

= 360° - 21°45'01"

= 338°14'59"

The accuracy ratio is calculated as the ratio of the closure error (E) to the sum of the traverse distances, or perimeter (P):

$$\text{Accuracy ratio} = \frac{E}{P}$$

$$\text{Accuracy ratio} = \frac{1}{(P \div E)} = \frac{1}{(1755.285 \div 0.27067)} = \frac{1}{6485} \approx \frac{1}{6500}$$

The denominator of the accuracy ratio is normally rounded off to the nearest 100. Therefore, the accuracy ratio is approximately $\frac{1}{6500}$. This is greater than the third order survey standard of $\frac{1}{5000}$, so this survey is acceptable.

Now that we know the survey is acceptable, let's go back and distribute the error in latitude and departure to each latitude and departure in proportion to the length of each course. Once this is complete, we can use the corrected latitudes and departures to determine coordinates of each station, and the bearings and distances between each station.

Step #6

How to distribute the error in Latitude and Departure to each side.

$$\text{Adjusted Latitude} = \text{Unadjusted Latitude} \pm (\text{error in latitude} \times \frac{\text{length of course}}{\text{total length of traverse}})$$

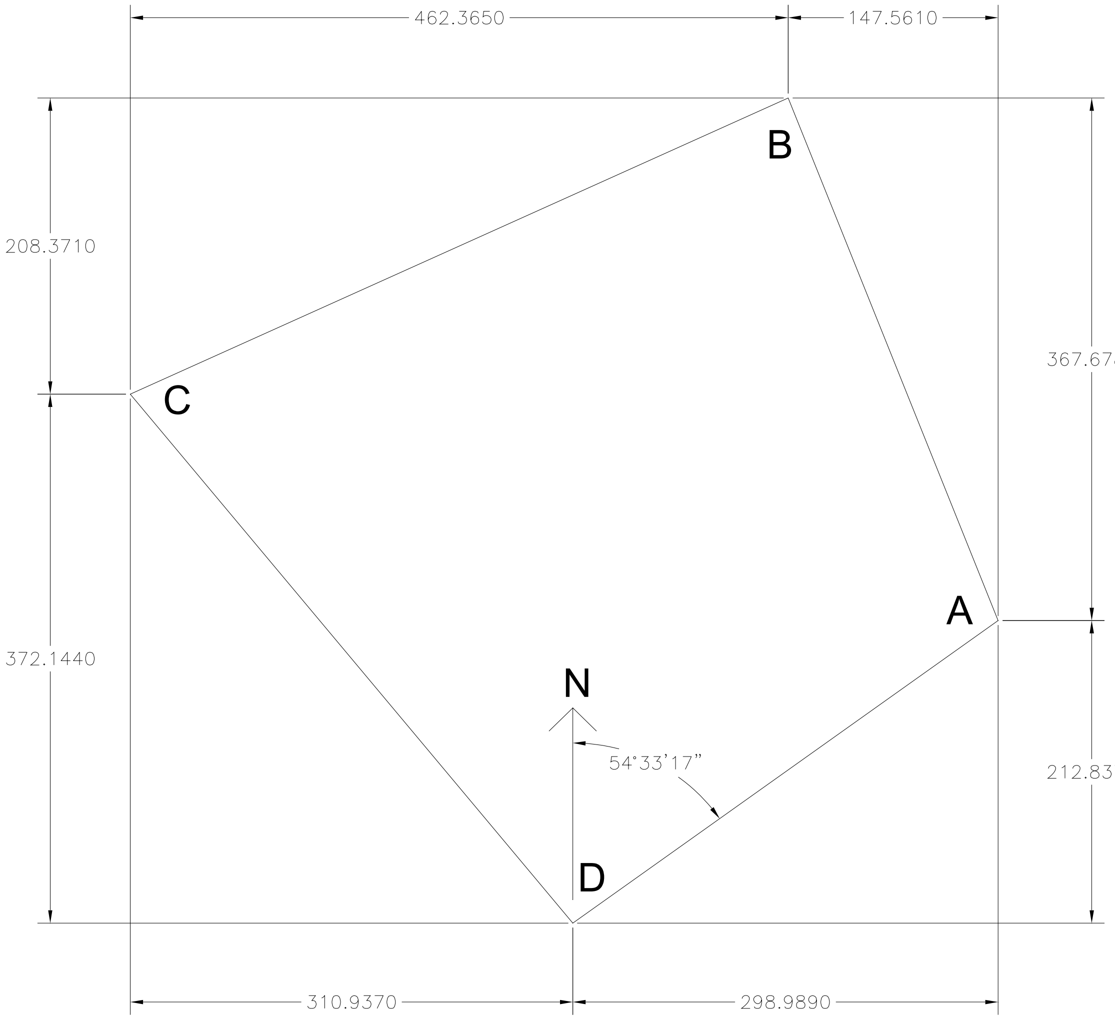
$$\text{Adjusted Departure} = \text{Unadjusted Departure} \pm (\text{error in departure} \times \frac{\text{length of course}}{\text{total length of traverse}})$$

For Example Course (A-B):

$$\text{Adjusted Latitude} = 367.7350 - (0.2514 \times \frac{396.245}{1755.285})$$

$$\text{Adjusted Departure} = -147.5842 + (0.1003 \times \frac{396.245}{1755.285})$$

Station	Adjustment to Latitude	Adjusted Latitude	Adjustment to Departure	Adjusted Departure
A				
	-0.0568	+367.6780	+0.0226	-147.5616
B				
	-0.0726	-208.3711	+0.0290	-462.3645
C				
	-0.0694	-372.1436	+0.0277	+310.9370
D				
	-0.0526	+212.8365	+0.0210	+298.9891
Totals (to check calculations)	-0.2514	-0.0002	+0.1003	0.0000



Step #7

Calculating Coordinates using adjusted Latitudes and Departures from step #6.

Start with the known coordinates of station D (5000,5000) and use the latitudes to calculate northings and departures to calculate eastings. (See table below)

Station	Northing	Easting
D	5000.000	5000.000
	+212.837	+298.989
A	5212.837	5298.989
	+367.678	-147.561
B	5580.515	5151.428
	-208.371	-462.365
C	5372.144	4689.063
	-372.144	+310.937
D	5000.000	5000.000

Step #8

Bearings and Lengths of all the courses using adjusted latitudes and departures.

$$\text{Adjusted Bearing} = \tan^{-1}\left(\frac{\text{departure}}{\text{latitude}}\right)$$

$$\text{Adjusted Length} = \sqrt{\text{departure}^2 + \text{latitude}^2}$$

Station	Adjusted Bearing	Adjusted Length
A		
	N 21°52'02" W	396.183
B		
	S 65°44'26" W	507.149
C		
	S 39°52'47" E	484.946
D		
	N 54°33'17' E	367.007
A		

This would complete a proper set of traverse calculations.

Problems

1. The interior angles of a five-sided traverse are:

A, 110° 27' 00"	D, 97° 33' 30"
B, 130° 52' 30"	E, ?
C, 88° 17' 00"	

   Determine the angle at E.

2. Convert the following azimuths to bearings:

   1. 241° 16'
   2. 145° 02'
   3. 167° 50'
   4. 280° 19'
   5. 21° 46'
   6. 333° 33'
   7. 191° 14'

3. Convert the following bearings to azimuths:

   1. N 71°50' W
   2. N 1°03' E
   3. S 14°53' E
   4. S 89°29' W
   5. N 89°08' E
   6. S 10°10’ W
   7. S 70°40' E

4. Convert the azimuths given in problem 2 to reverse (back) azimuths.

5. Convert the bearings given in problem 3 to reverse (back) bearings.

6. The deflection angles for open traverse ABCDEFGH are:

B; 8°13' right	E; 21°08' left
C; 2°21' right	F; 6°32' left
D; 14°41' right	G; 1°15' right

The bearing of AB is N 41°21' E. Determine the bearings of the other courses.

7. The bearings of closed traverse ABCD are:

AB; N 60°38' E	CD; S 17°13' W
BC; S 49°49' E	DA; N 58°49' W

Determine the interior angles. Check the angles geometrically.

8. The stations of a five-sided closed traverse are labelled clockwise A, B, C, D, and E with station A being the most westerly station. The interior angles of the traverse are listed below:

A: 63° 47' 00";	B: 140° 28' 50";	C: 101° 30' 20";
D: 72° 48' 10";	E: 161° 25' 40"	

If the bearing of course AB is N 30°38'10" E, determine the bearings of the remaining sides. Provide two solutions; one solution proceeding clockwise, and the other solution proceeding counter-clockwise.

9. If the azimuth of course AB in the previous problem is 51° 44', determine the azimuths of the remaining sides. Proceed in a clockwise direction.

10. The stations of a five-sided closed traverse are labelled counter-clockwise A, B, C, D, and E with station A being the most easterly station. The interior angles of the traverse are listed below:

A: 83° 26' 47";	B: 131° 50' 31";	C: 136° 06' 43";
D: 43° 24' 49";	E: 145° 11' 10"	

If the azimuth of course AB is 274° 13' 28", determine the azimuths of the remaining sides. Provide two solutions; one solution proceeding clockwise, and the other solution proceeding counter-clockwise.

11. If the bearing of course AB in the previous problem is N 72° 22' 15" W, determine the bearings of the remaining sides. Proceed in a counter-clockwise direction.

12. The two frontage corners of a large tract of land were joined by the following open traverse:

Course	Distance (m)	Bearing
AB	24.482	N 70°10'07" E
BC	290.727	N 74°29'00" E
CD	249.476	N 70°22'45" E

Determine the distance and bearing of the property frontage AD.

13. A six-sided traverse has the following station coordinates:

Station	Northing (m)	Easting (m)
A	559.319	207.453
B	738.562	666.737
C	541.742	688.350
D	379.861	839,008
E	296.099	604.048
F	218.330	323.936

1. Compute the distance and bearing of each side;

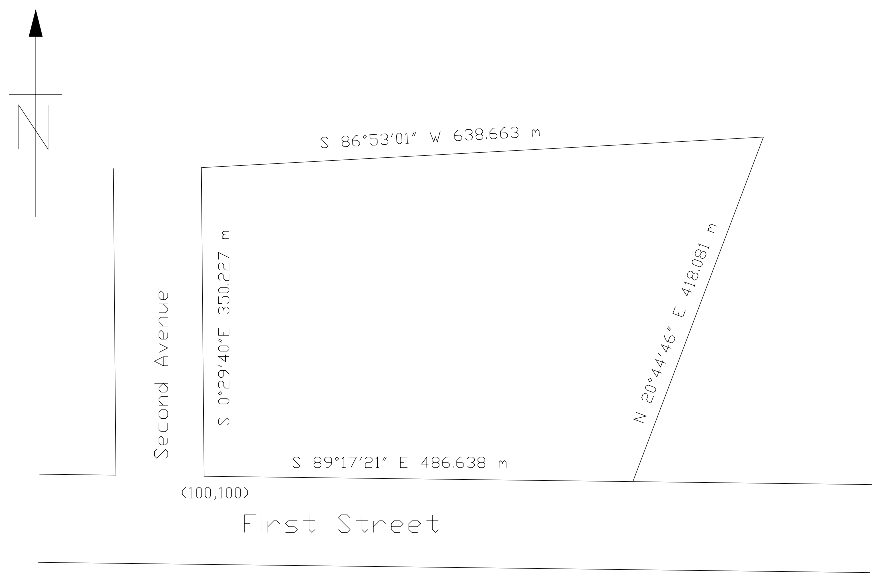
2. If the intersection point of lines AD and BF is K and if the intersection point of lines AC and BE is L, compute the distance and bearing of line KL.

14. The following azimuths and distances to the corners of a five-sided property were taken by an EDM at control point K, located within the property:

Direction	Azimuth	Hor. Distance (m)
KA	286°51' 30"	34.482
KB	37°35' 28"	31.892
KC	90°27' 56"	38,286
KD	166°26' 49"	30.585
KE	247°28' 43"	32.585

If the co-ordinates of K are (1990.000 N, 2033.000 E), determine the co-ordinates of the property corners A, B, C, D, and E.

15. A lot is located at an intersection as shown below. The owner would like to divide this existing lot into two pieces. Calculate the distance and bearing of a new lot line that would start at the midpoint of the frontage of the lot and end at the midpoint of the rear lot line. The frontage is the longest property line that is abutting a roadway, while the rear lot line is opposite the frontage. The co-ordinates of the south-west corner of the lot are (100.000, 100.000).



SURVEYING SURV EA141 / CV104
MODULE 5: TOTAL STATIONS AND LASER LEVELS

In today's world, technology is in constant evolution. Little more than two decades ago, theodolites and tapes were still commonly used. Now total station surveys are considered a "traditional survey" method, as GPS and other technologies have become common place in the industry. This module looks at what a total station is, and how it is capable of measuring. In addition, this module covers some basics of laser levelling.

Obj #	Learning Objective	Resources
5.1	What is a "total station"? How does it differ from an EDM?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figures 5-A to 5-F
5.2	What does a total station measure? What does it calculate?	Lecture/bb.mohawkcollege.ca Ref. Text 1
5.3	What is a "data collector" and what kinds exist? Is note keeping required when a data collector is used?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figures 5-G to 5-J
5.4	What errors are associated with total station use? How can they be avoided?	Lecture/bb.mohawkcollege.ca Ref. Text 1
5.5	What is a "laser level"? What kinds are used for surveying and construction?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figures 5-K to 5-N
5.6	How is a laser level used? What equipment is required?	Lecture/bb.mohawkcollege.ca Ref. Text 1
5.7	What errors are associated with the use of a laser level?	Lecture/bb.mohawkcollege.ca Ref. Text 1
5.8	Example Questions and Answers	
5.9	Problems	

Obj. 5.1
Total Stations at Mohawk College

Wild T1000
Fig 5-A

Topcon CTS-2
Fig 5-B

Topcon GTS-313
Fig 5-C

Leica TC410C
Fig 5-D

Obj. 5.1 (con't)
A couple examples of EDM's

Leica Disto A3
Fig 5-E

Stanley TLM 300
Fig 5-F

Obj. 5.2

Although a total station is a very powerful survey instrument it measures only 3 pieces of information. Everything else it can do is based on calculations that are performed using this data. A total station measures:

- vertical (zenith) angle
- slope distance
- horizontal angle

Obj. 5.3
Examples of external data collectors

TDS Recon (here at Mohawk)
Fig 5-G

TDS Nomad
Fig 5-H

TDS Ranger
Fig 5-I

Topcon GMS-2
Fig 5-J

Obj 5.5
Examples of Laser Levels

Construction Level Topcon RL-H3C
Fig 5-K

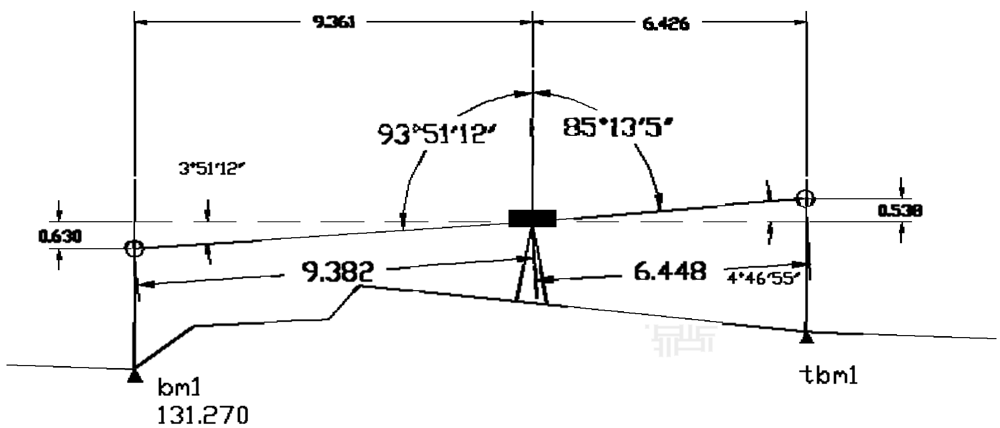
Interior Level Topcon RL-VH3D
Fig 5-L

Slope Level Topcon RT-5SB
Fig 5-M

Pipe Level Topcon TP-L4BG
Fig 5-N

Example Questions and Answers

1.



A total station set up as shown above could be used to establish the elevation of tbm1. The only information that would be measured by the total station would be the slope distances and zenith angles to each point (these are shown in large print). The horizontal angle would also be measured but is not used in this calculation and so is not shown.

Because the instrument is looking downhill to bm1 the zenith angle is greater than 90°. Indeed it is equal to 93° 51' 12". This means that the angle between the line of sight to the prism at bm1 and the horizontal is 93° 51' 12" - 90° = 3° 51' 12" (as shown in small print). The slope distance that was measured to bm1 (also shown in large print) forms the hypotenuse of a right angle triangle for which we know the values of the interior angles. The side opposite the 3° 51' 12" angle is the vertical distance between the prism and the total station. The side adjacent to the angle is the horizontal distance.

These sides can be found from trigonometry as shown below.

$$\sin 3°\,51'\,12'' = \frac{\text{opp}}{\text{hyp}} = \frac{\text{vertical dist}}{9.382}$$

$$\text{so vertical dist} = \sin 3°\,51'\,12'' \times 9.382 = 0.630$$

likewise;

$$\cos 3° 51' 12'' = \frac{\text{adj}}{\text{hyp}}$$

$$= \frac{\text{horizontal dist}}{9.382}$$

so horizontal dist = cos 3° 51' 12" x 9.382
= 9.361

The total station is looking uphill at tbm1 and as a result the zenith angle is less than 90°. For this example it is equal to 85° 13' 5". This means that the angle between the line of sight to the prism at tbm1 and the horizontal is 90° - 85° 13' 5"= 4° 46' 55" (as shown in small print). The slope distance that was measured to bm1 (also shown in large print) equals 6.448 and again forms the hypotenuse of a right angle triangle for which we know the values of the interior angles. As before we can calculate;

$$\sin 4° 46' 55'' = \frac{\text{opp}}{\text{hyp}}$$

$$= \frac{\text{vertical dist}}{6.448}$$

so vertical dist = sin 4° 46' 55" x 6.448
= 0.538

and;

$$\cos 4° 46' 55'' = \frac{\text{adj}}{\text{hyp}}$$

$$= \frac{\text{horizontal dist}}{6.448}$$

so horizontal dist = cos 4° 46' 55" x 6.448
= 6.426

If we know the height that the prism is set at (say 1.500 m above bm1) we can calculate the elevation of tbm1 as follows;

Bm1 elev + prism height + vertical = HI
HI + vertical = prism elevation
Prism elevation – prism height = Elev tbm1

So . . . 131.270 + 1.500 + 0.630 = 133.400
133.400 + .538 = 133.938
133.938 – 1.500 = 132.438

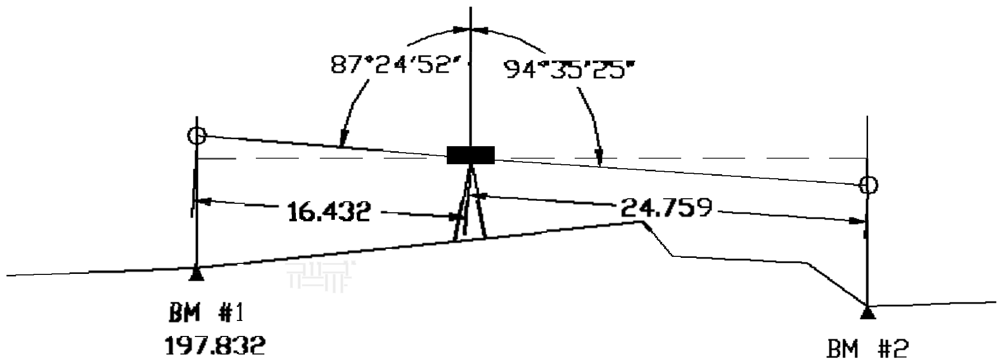
Thankfully these calculations are performed by the instrument and you need only press the appropriate button to view the results.

2. Why should you not lift a total station by the telescope?

Lifting a total station (or any survey instrument) by the telescope can cause damage to the instrument. To avoid damage to a total station the proper procedure for moving the instrument is to remove it from the tripod and place it back in the case. For your initial set-up you should carry the instrument in the case and only attach it to the tripod when you are where the instrument is to be stationed.

Problems

1. Given the following total station set-up, calculate the elevation of BM # 2. The height of the prism is 1.350 m.



2. What is an “optical plummet”? How is it used?

3. Name the three basic components that make up a total station unit.

4. What three pieces of information are recorded by a total station? What information can be calculated from these?

5. What options are available for automatic data collection when using a total station?

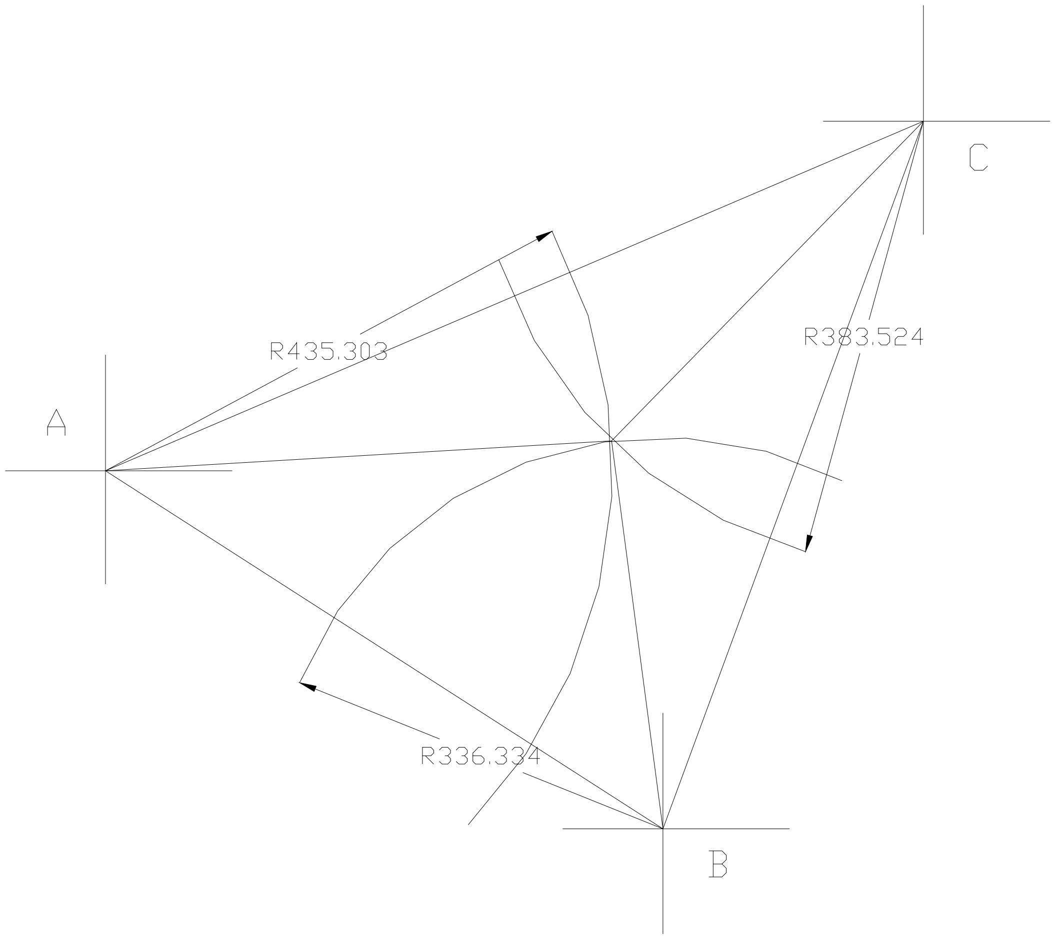
6. Describe how a rotating laser level could be used to check the elevation on a construction site.

SURVEYING SURV EA141 / CV104
MODULE 6: GPS/GNSS

Global Navigation Satellite Systems (GNSS) is the generic term for any satellite positioning system regardless of its country of original. For over three decades the American's Global Positioning System (GPS) has been the standard. Other countries are jumping on board and creating or updating their systems to compete. GNSS is finding its way into everyday recreational and vehicular applications but is also used in many other ways. This module explains GNSS/GPS technology and describes how it is used in the practice of surveying.

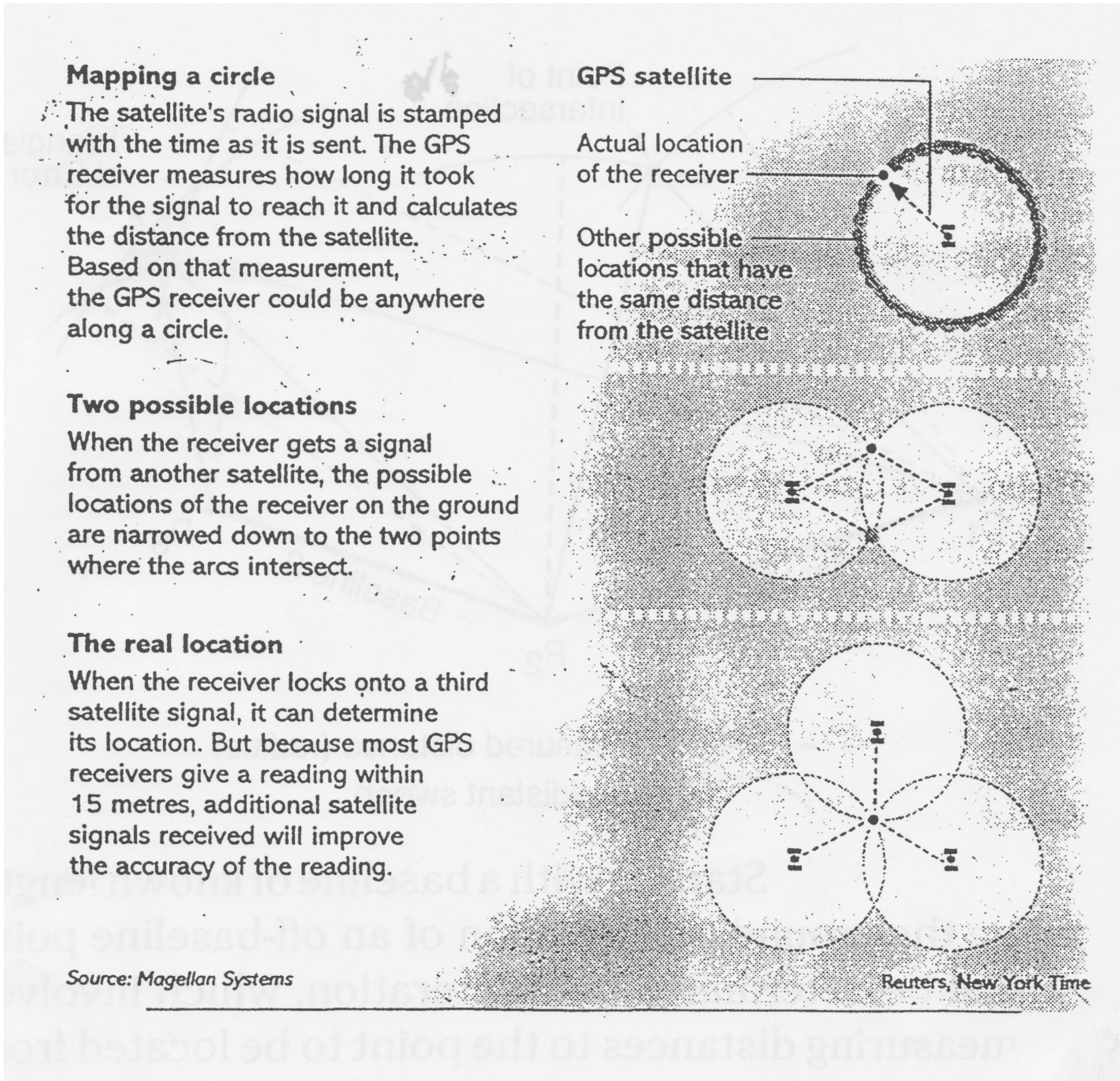
Obj #	Learning Objective	Resources
6.1	What is a GNSS? How did it originate?	Lecture/bb.mohawkcollege.ca Ref. Text 1
6.2	What are GPS, GLONASS, Galileo, and COMPASS/Beidou?	Lecture/bb.mohawkcollege.ca Ref. Text 1
6.3	What is trilateration? How does this enable one to define a position?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 6-A
6.4	How does GPS/GNSS work?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 6-B
6.5	How are distances to satellites measured?	Lecture/bb.mohawkcollege.ca Ref. Text 1
6.6	How are timing issues addressed?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 6-C
6.7	How are the position of satellites in space determined?	Lecture/bb.mohawkcollege.ca Ref. Text 1
6.8	What errors can occur using GPS/GNSS? What corrections can be made?	Lecture/bb.mohawkcollege.ca Ref. Text 1
6.9	What modifications to basic GPS/GNSS are made for surveying purposes?	Lecture/bb.mohawkcollege.ca Ref. Text 1
6.10	What is "mission planning"? Why is it necessary?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 6-D
6.11	Example Questions and Answers	
6.12	Problems	
6.13	Internet References	

Obj. 6.2



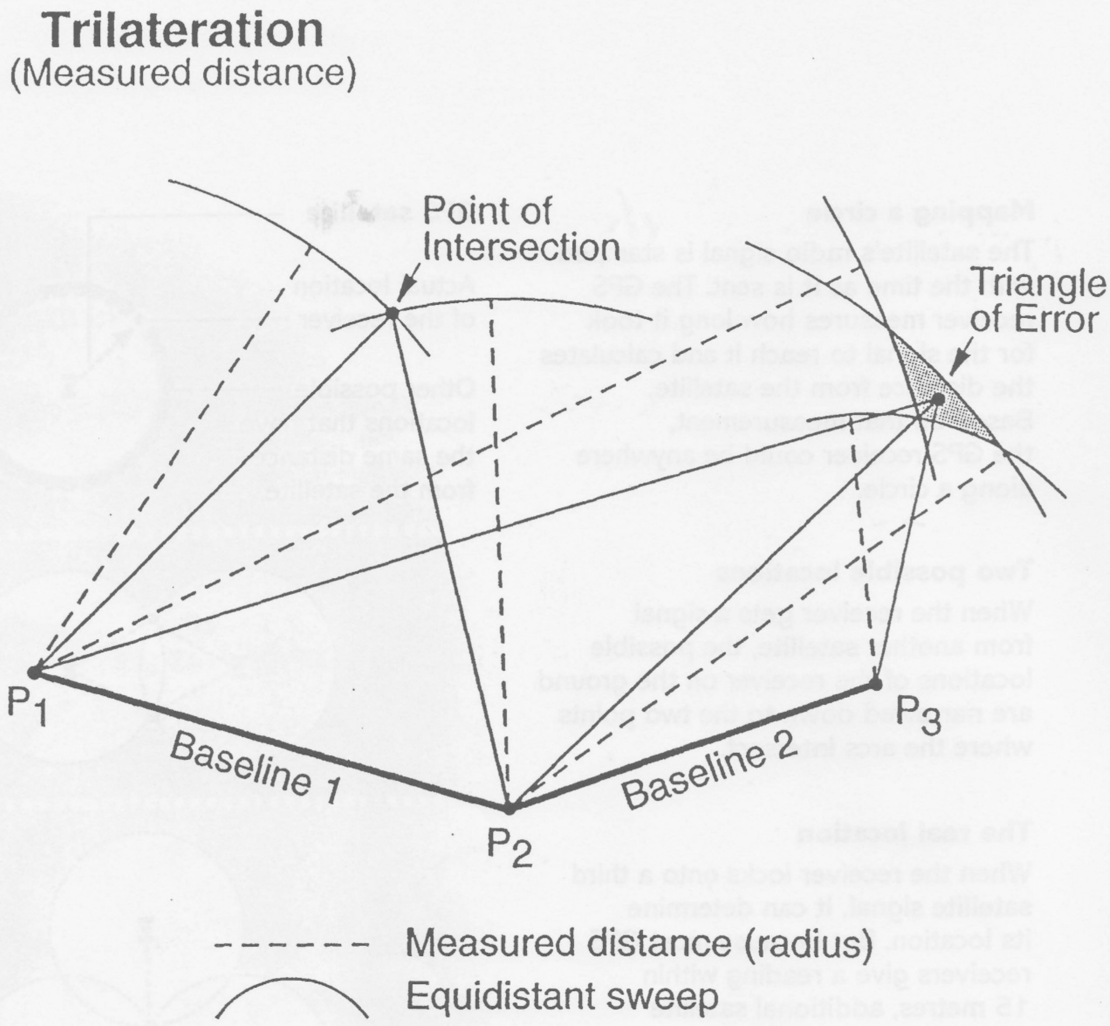
Example of Trilateration
Figure 6 - A

Obj. 6.3



Calculation of Location using GPS
Figure 6 - B

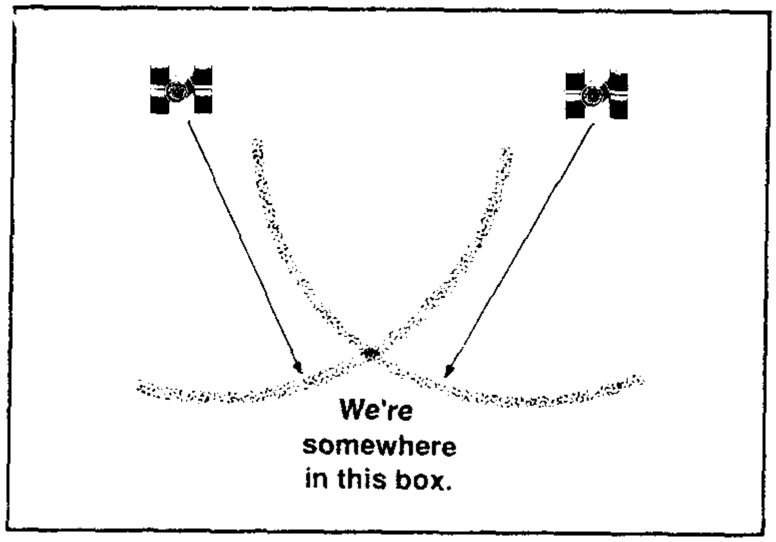
Obj. 6.5



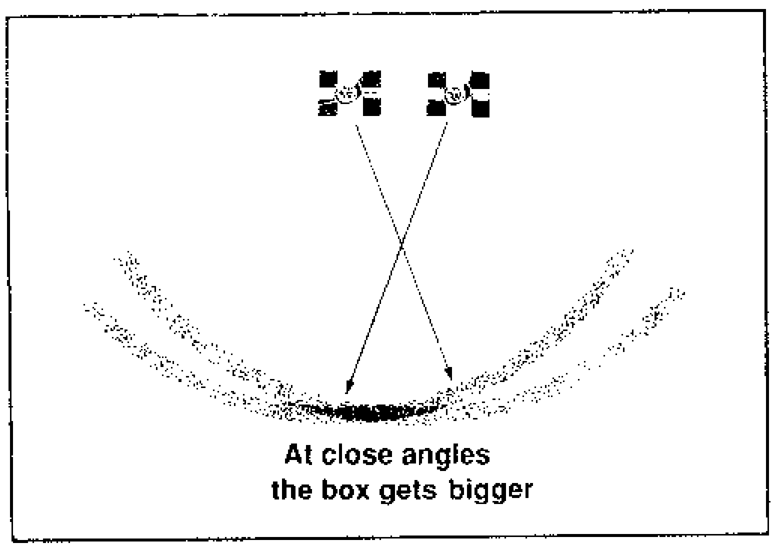
Starting with a baseline of known length on the ground, the position of an off-baseline point can be determined by trilateration, which involves measuring distances to the point to be located from the ends of the baseline.

Effect of Timing Errors on Location Calculation
Figure 6 - C

Obj. 6.9



(a)



(b)

Effect of Geometry on Location Calculation
Figure 6 - D

Example Questions and Answers

1. What is the basis on which GPS/GNSS calculates location?

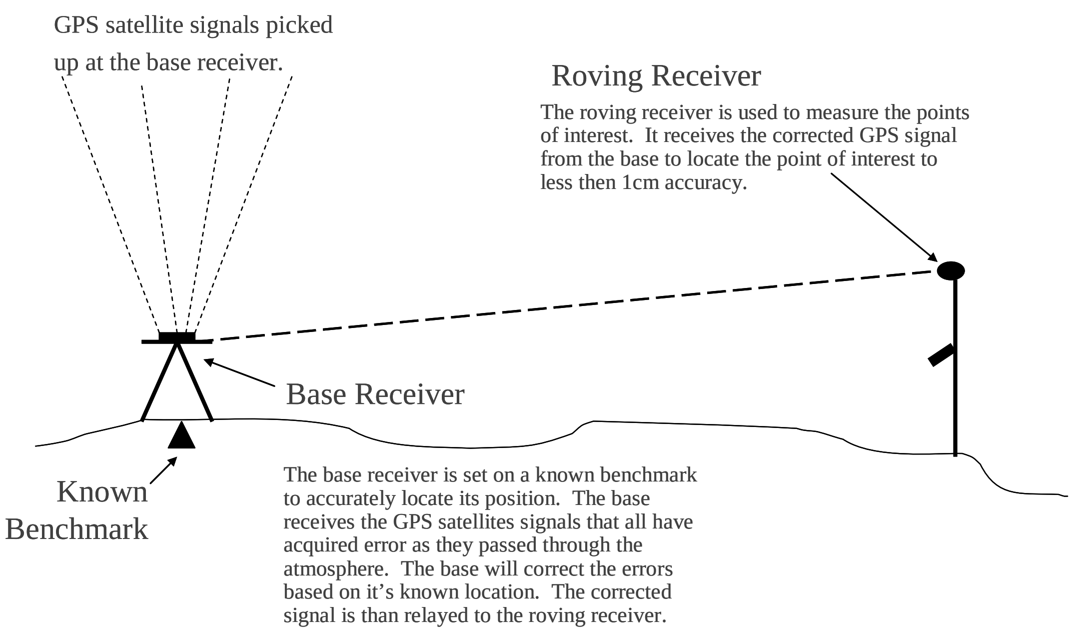
   GPS/GNSS uses trilateration from satellites to determine position. The computer software on the receiver uses the data from a minimum of four satellites to define a position by calculating the distance from each satellite to the receiver. Only one point will lie at the intersection of these four distances as measured from the four satellites. This process is sometimes called satellite ranging.

2. Are the atomic clocks in GPS satellites radio active?

   No. Atomic refers to the fact that they keep time by measuring the oscillations of a particular atom.

3. What modification is made to GPS/GNSS in order to use it for surveying?

   Differential GNSS is used in surveying. This involves locating a "base" unit over top of a point whose location is known. It then continuously calculates the difference between its known position and the position as calculated by the satellites. The difference between the two is the error and this information is sent to the "rover" unit that is collecting the survey points, so that the appropriate corrections can be made.



Problems

1. Four countries are currently maintaining or building a Global Navigation Satellite System (GNSS). List the four countries and the corresponding name of their GNSS.

2. Why is it necessary to receive radio signals from a minimum of four satellites to unambiguously define a position?

3. Which atom's oscillation is measured as a means of keeping time in an atomic clock?

4. List and explain two types of errors that can occur in using GPS technology.

5. What is "ephemeris" data? How is it calculated?

6. Apart from surveying list three other uses for GPS technology.

Internet References

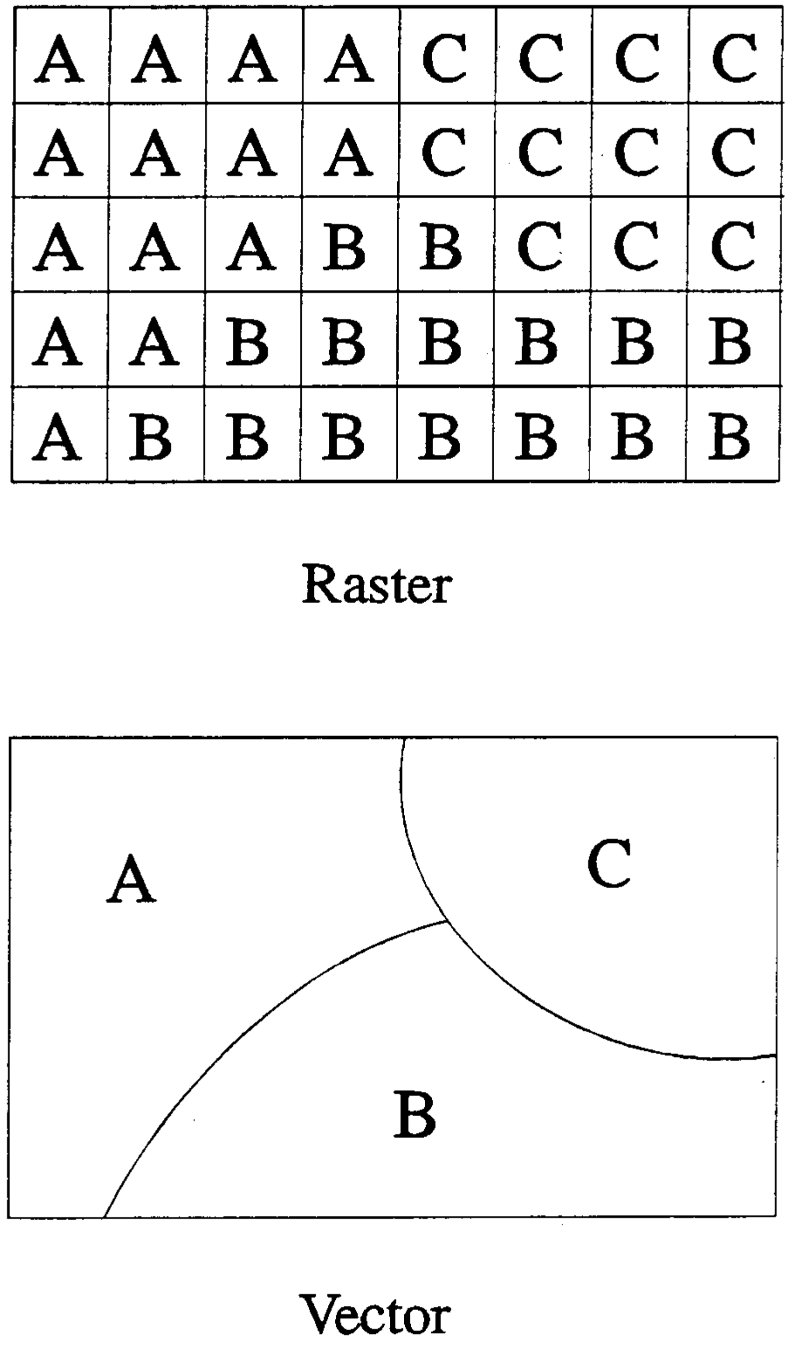
Garmin:	http://www8.garmin.com/aboutGPS/
Trimble:	http://www.trimble.com/gps/index.shtml
Inside GNSS periodical:	http://www.insidegnss.com/

SURVEYING SURV EA141 / CV104
MODULE 7: GIS

Geographic Information Systems (GIS) are very important as a design and analysis tool. They are being applied to a wide variety of activities including agriculture, medical science, wildlife management and more. In building and construction a GIS is heavily used for inventory and management of infrastructure in the world around us. A GIS relies on accurate and precise data for it to be effective. Surveying is just one of the many sources of data in a GIS. This module describes what a GIS is and its relationship to surveying.

Obj #	Learning Objective	Resources
7.1	What is an "information system"?	Lecture/bb.mohawkcollege.ca Ref. Text 1
7.2	How does a GIS differ from an ordinary information system?	Lecture/bb.mohawkcollege.ca Ref. Text 1
7.3	How is GIS related to the practice of surveying?	Lecture/bb.mohawkcollege.ca Ref. Text 1
7.4	What does a GIS consist of?	Lecture/bb.mohawkcollege.ca Ref. Text 1
7.5	What is "spatial data"? What role does it play in a GIS?	Lecture/bb.mohawkcollege.ca Ref. Text 1
7.6	What is a "data model"? What types exist?	Lecture/bb.mohawkcollege.ca Ref. Text 1 Figure 7-A
7.7	Define "topology" and its role in a GIS.	Lecture/bb.mohawkcollege.ca Ref. Text 1
7.8	What kinds of analysis can be performed with a GIS? What functions are used?	Lecture/bb.mohawkcollege.ca Ref. Text 1
7.9	What applications exist for a combination of GIS and GPS?	Lecture/bb.mohawkcollege.ca Ref. Text 1
7.10	Example Questions and Answers	
7.11	Problems	
7.12	Internet References	

Obj. 7.6



Raster and Vector Data Models
Figure 7-A

Example Questions and Answers

1. List the fundamental components of a GIS.

   In its most basic form a GIS can be thought of as a type of computer software that is operated on a particular configuration of computer hardware and that uses a specialized database. The database is the key component to the system and also the most time consuming and costly to create.

2. In what way is surveying related to GIS?

   GIS is not a method of measuring the location or elevation of things. Rather it is able to do calculations based on a "knowledge" of where items are located and how their positions are related to one another. Surveying therefore is used, along with other areas of geomatics, as a means of producing and checking the necessary geo-referenced data that a GIS system needs to operate.

3. What are the two major GIS data models which are used?

   The two major GIS data models are known as the raster and vector models. Raster models divide a study area into cells and assign a value to each cell. The vector model uses 0-D to 3-D objects to define and describe the study area.

4. What software is available to perform GIS operations? How does it work?

   While there are several GIS related software packages available, Mohawk College has purchased and teaches an ERSI product called "ArcView". It comes complete with a sample database for a region of Atlanta Georgia in the United States. Using this database it is possible to perform various "queries" and obtain the answers to these questions. If time permits a demonstration of this software will be given in class.

Problems

1. Why is a GIS sometimes referred to as a “smart map”?

2. How does “spatial” data differ from “non-spatial” data? Give an example of each.

3. Usually a database is created from a model of some aspect of the real world. Why is this necessary?

4. What is meant by the term topology?

5. Describe the effect and give an example of when the GIS operation of “buffering” might be used.

6. Give 3 examples of how municipalities in North America are using Geographic Information Systems.

Internet References

ESRI: http://www.esri.com/